SERVICE MANUAL
WRIGHT AIRCRAFT ENGINES
CYCLONE 9HC

DESTROYED

WRIGHT AERONAUTICAL CORPORATION
A DIVISION OF CURTISS-WRIGHT CORPORATION
PATERSON, NEW JERSEY, U. S. A.

National Gypsum Co.

N 1550

A.R.C. Receiver

NOTICE

Army-Navy policy, established since these instructions were printed, standardized on the term "Water Injection" for the method of injecting anti-detonant liquid. For this reason, Wright Aeronautical Corporation will no longer use the term "Anti-Detonant Injection" ("ADI") but will conform to Army-Navy policy and use the term "Water Injection."

WRIGHT *Cyclone* ENGINES

SERIES

9HC

SERVICE MANUAL

SECOND EDITION — JANUARY, 1945

PART NO. 855689-N2

RESTRICTED

WRIGHT AERONAUTICAL CORPORATION

A DIVISION OF CURTISS-WRIGHT CORPORATION

PATERSON, NEW JERSEY, U.S.A.

PRINTED IN U.S.A.

NOTICE

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This publication is for the information of maintenance personnel. Should information contained herein be in conflict with Army or Navy Air Forces publications, instructions in such publications will be governing and no action by service activities on any information contained herein is authorized.

FOREWORD

This Service Manual has been written for those persons who are concerned with the ground operation and servicing of the Wright Cyclone 9HC engines as designed by the Wright Aeronautical Corporation.

The information included herein supersedes that which was published in the first edition of the Cyclone 9HC Service Manual. This manual was rewritten to incorporate instructions pertaining to later design features of the engine as well as improved service procedures based on experience gained since the issuance of the earlier edition. It is urgently recommended that these instructions be followed closely for all normal conditions and that the Wright Aeronautical Corporation be consulted before any deviation is made.

Many new features are incorporated in this manual as an aid to understanding and efficiency: cutaway views show relative position of parts, and demonstrate the engine lubrication system; a Table of Differences between Models illustrates at a glance the difference in model types and their variants; and the inspection routine and the analysis of engine troubles are presented in chart form.

For the benefit of its customers, the Wright Aeronautical Corporation issues separate publications which will be supplied to owners of Wright engines at no charge, upon request. For non-owners, a price list of publications will be supplied upon request.

TABLE OF LIMITS These tables, Part No. 855349, contain reference numbers and descriptions for the service clearances which must be maintained in the engine, and are to be used in conjunction with the Limits and Lubrication Charts described in the subsequent paragraph.

LIMITS AND LUBRICATION CHARTS These 20 x 30 inch charts, Parts No. 853569, 853573, 854533, 854534, 854535, which are to be used in conjunction with current editions of the Table of Limits, contain reference numbers indicating the location of fits and clearances. They also indicate the engine lubrication system in color.

PARTS REFERENCE CHARTS These charts, which show major engine assemblies in exploded form with each part labeled for easy reference, are available in two forms. One set, Part No. 854561, consists of charts (30 x 40 inches), and the other, Part No. 854876, is a booklet of reduced reproductions.

The Wright Aeronautical Corporation maintains a Customers' Service School which offers a series of familiarization courses on all current engine models produced by the company. The courses are based mainly on engine characteristics and performance, mechanical features of the engine, inspection of parts, and the use of special tools. In addition, a flight engineers course on power control is offered. It should be emphasized, however, that these facilities are useful primarily for model familiarization; no advanced training in either engine operation or overhaul is attempted. It is requested that notice be given of prospective students in order to coordinate instruction.

The Wright Aeronautical Corporation welcomes suggestions for improving its engines and its service and would like to receive your recommendations on this manual. Any suggestions of this nature are greatly appreciated and will receive our careful consideration. Please address all such suggestions, as well as requests for any desired information which is not included in this manual, to the Wright Aeronautical Corporation, specifying the model designations of the engines in which you are interested.

WRIGHT GUARANTEE

We warrant each new engine manufactured by us to be free from defects in material and workmanship under normal use and service and proper installation; our obligation under this warranty being limited to making good at our factory any part or parts thereof, which shall, within ninety (90) days after delivery of such engine to the original purchaser, be returned to us with transportation charges prepaid, and which our examination shall disclose to our satisfaction to have been defective; this warranty being expressly in lieu of all warranties, expressed or implied, and of all other obligations or liabilities on our part; and we neither assume nor authorize any other person to assume for us any other liability in connection with the sale of our engines.

This warranty does not cover any labor charges for the replacement of parts, adjustments, repairs, or any other work done on Wright engines.

This warranty shall not apply to any engine which shall have been repaired or altered outside of our factory in any way, so as, in our judgment, to affect its performance or reliability, or which has been subject to misuse, negligence, or accident, or which shall have been operated at powers or speeds in excess of the engine specification limitations.

This warranty shall not apply to any engine which shall have been operated with other than specified fuel and oil.

We reserve the right to revise, change, or modify the whole or any part of the construction of Wright engines, without incurring any obligation to make the changes on engines previously sold.

We make no warranty whatever in respect to ignition, starting devices, generators, carburetors, or other trade accessories, inasmuch as these are usually warranted separately by their respective manufacturers.

WRIGHT AERONAUTICAL CORPORATION
A Division of Curtiss-Wright Corporation
Paterson, New Jersey, U. S. A.

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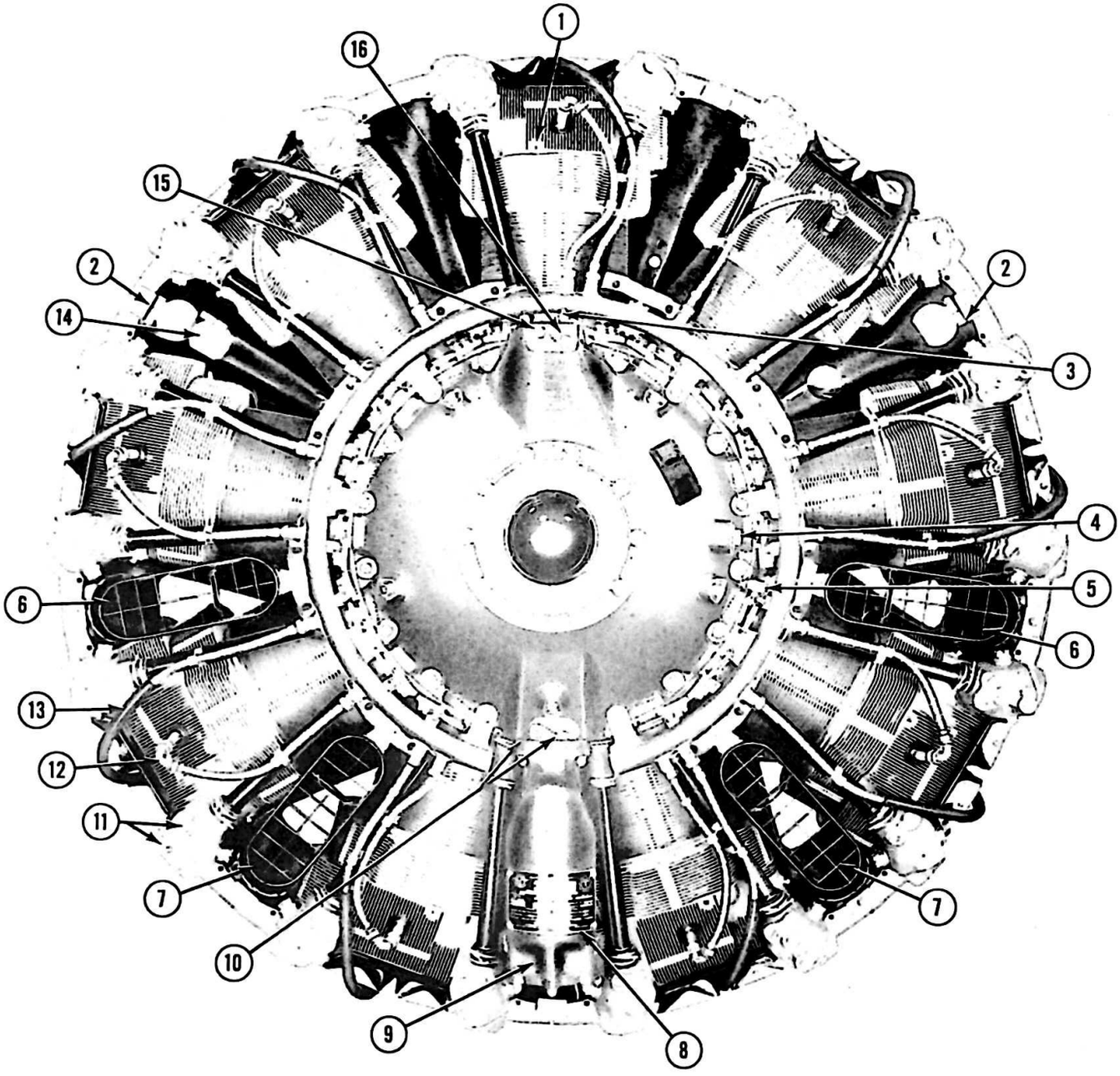
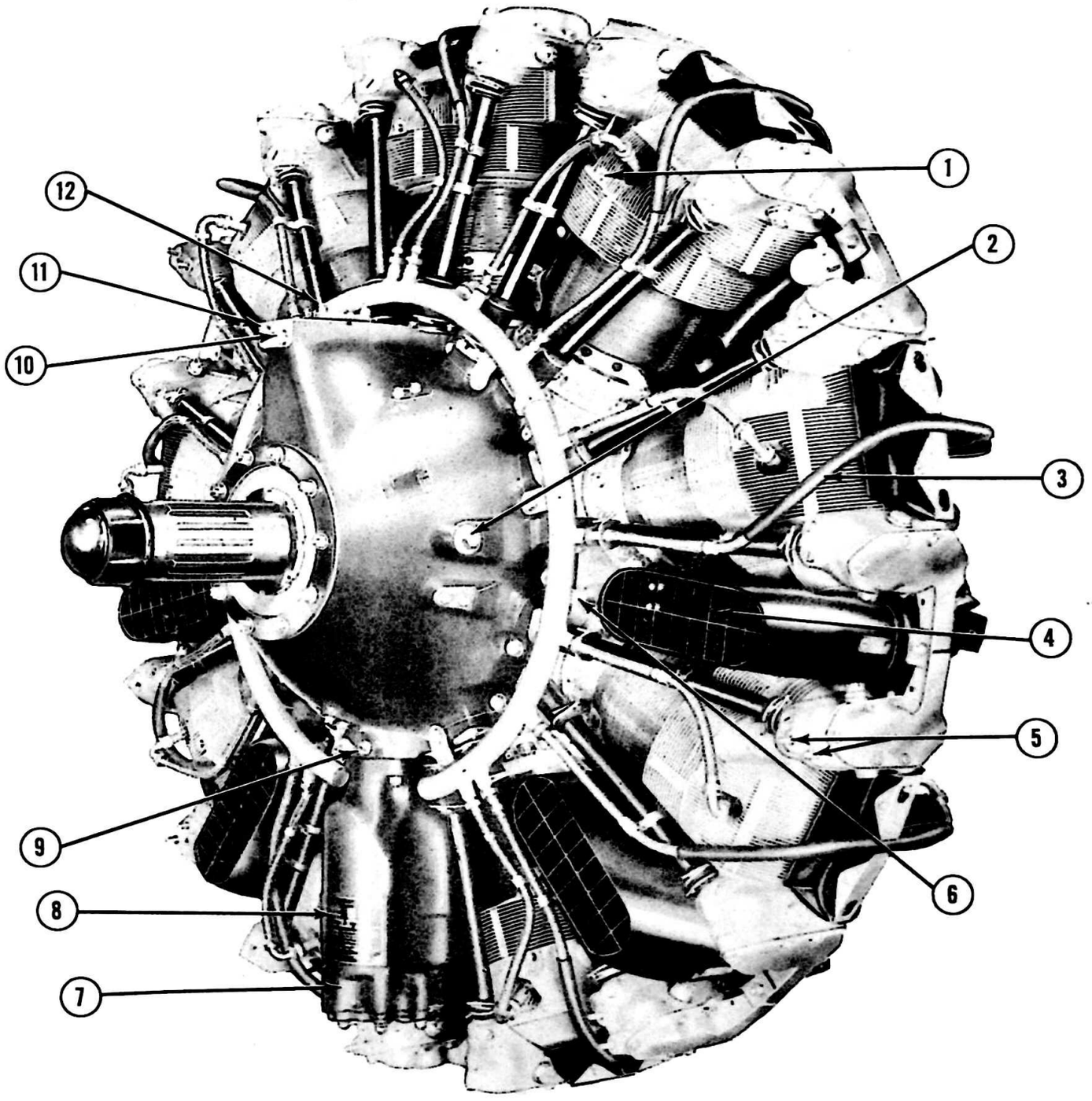


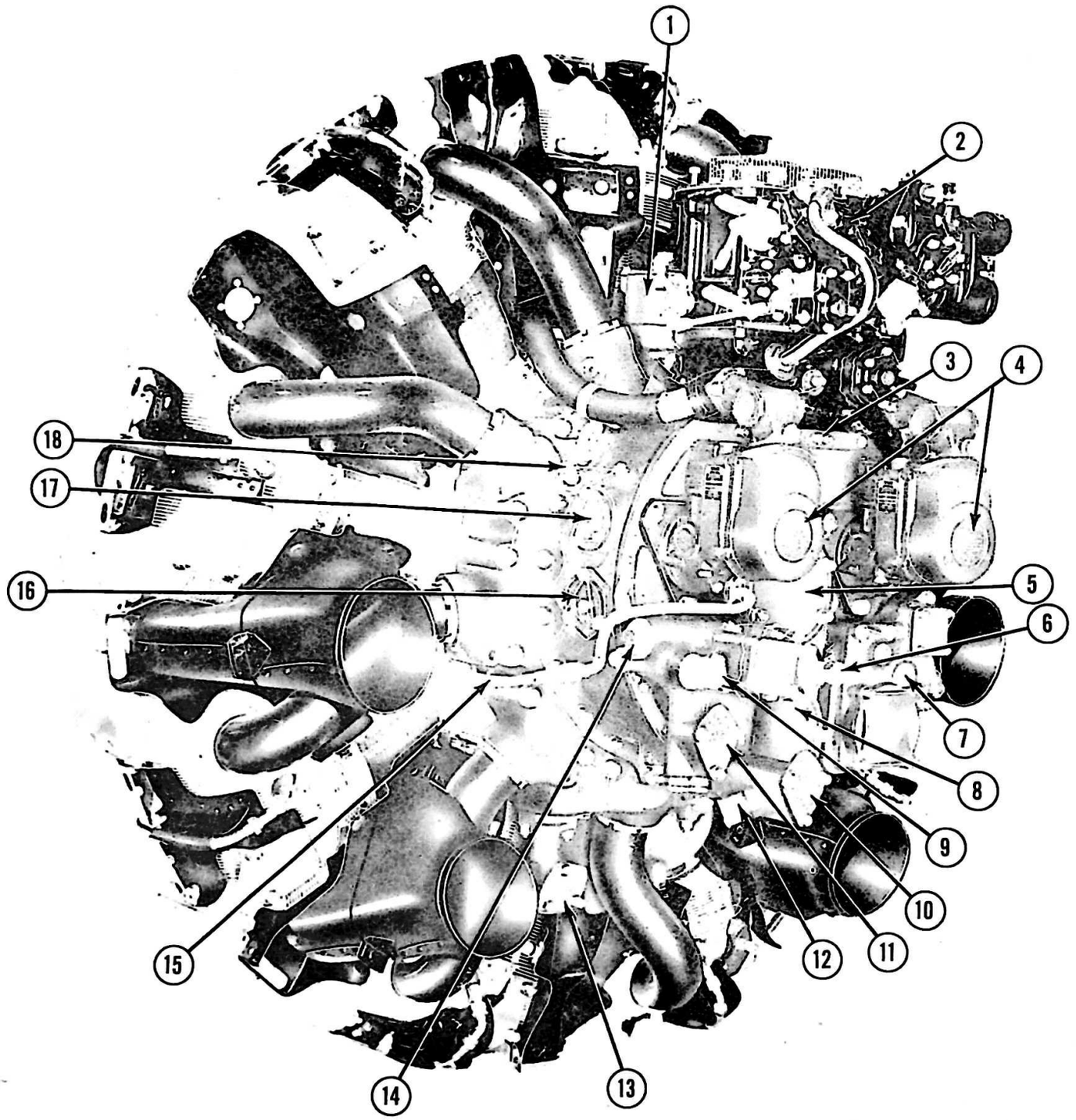
1. THERMOCOUPLE CONNECTION (DETONATOR INDICATOR)
2. MAGNETO BLAST TUBE FITTING
3. GOVERNOR PUMP MOUNTING PAD
4. TIMING INSPECTION HOLE PLUG
5. EXTERNAL HYDRO-OIL LINE
6. CARBURETOR AIR SCOOP DUCT
7. OIL COOLER DUCT
8. ENGINE DATA PLATE
9. FRONT SUMP SCAVENGE PUMP
10. DRAIN PLUGS
11. COWL MOUNTING STUDS
12. SPARK PLUG TERMINAL ELBOW
13. REAR SPARK PLUG CONDUIT
14. CABIN HEATER BLAST TUBE
15. GOVERNOR OIL PRESSURE PLUG
16. ENGINE OIL PRESSURE PLUG

Figure 1—Full Front Engine View



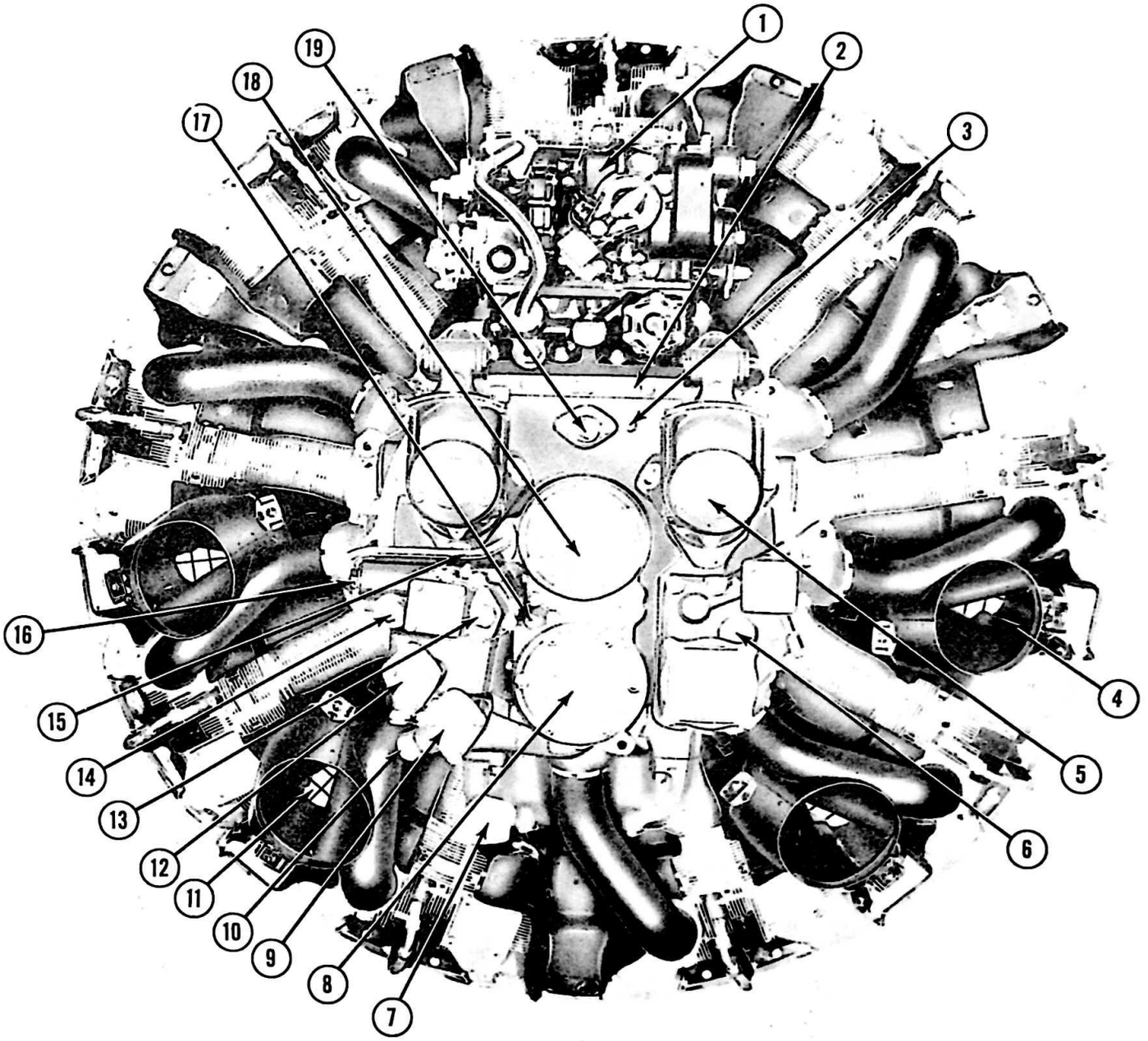
1. THERMOCOUPLE CONNECTION (DETONATOR INDICATOR)
2. TIMING INSPECTION HOLE PLUG
3. REAR SPARK PLUG CONDUIT
4. CARBURETOR AIR SCOOP FUNNEL
5. COWL MOUNTING STUDS
6. EXTERNAL HYDRO-OIL LINE
7. FRONT SUMP AND SCAVENGE PUMP ASSEMBLY
8. ENGINE DATA PLATE
9. CRANKCASE FRONT SECTION DRAIN PLUGS
10. ENGINE OIL PASSAGE PLUG
11. HYDRO-OIL PASSAGE PLUG
12. GOVERNOR MOUNTING PAD

Figure 2—Three-Quarter Left Front View



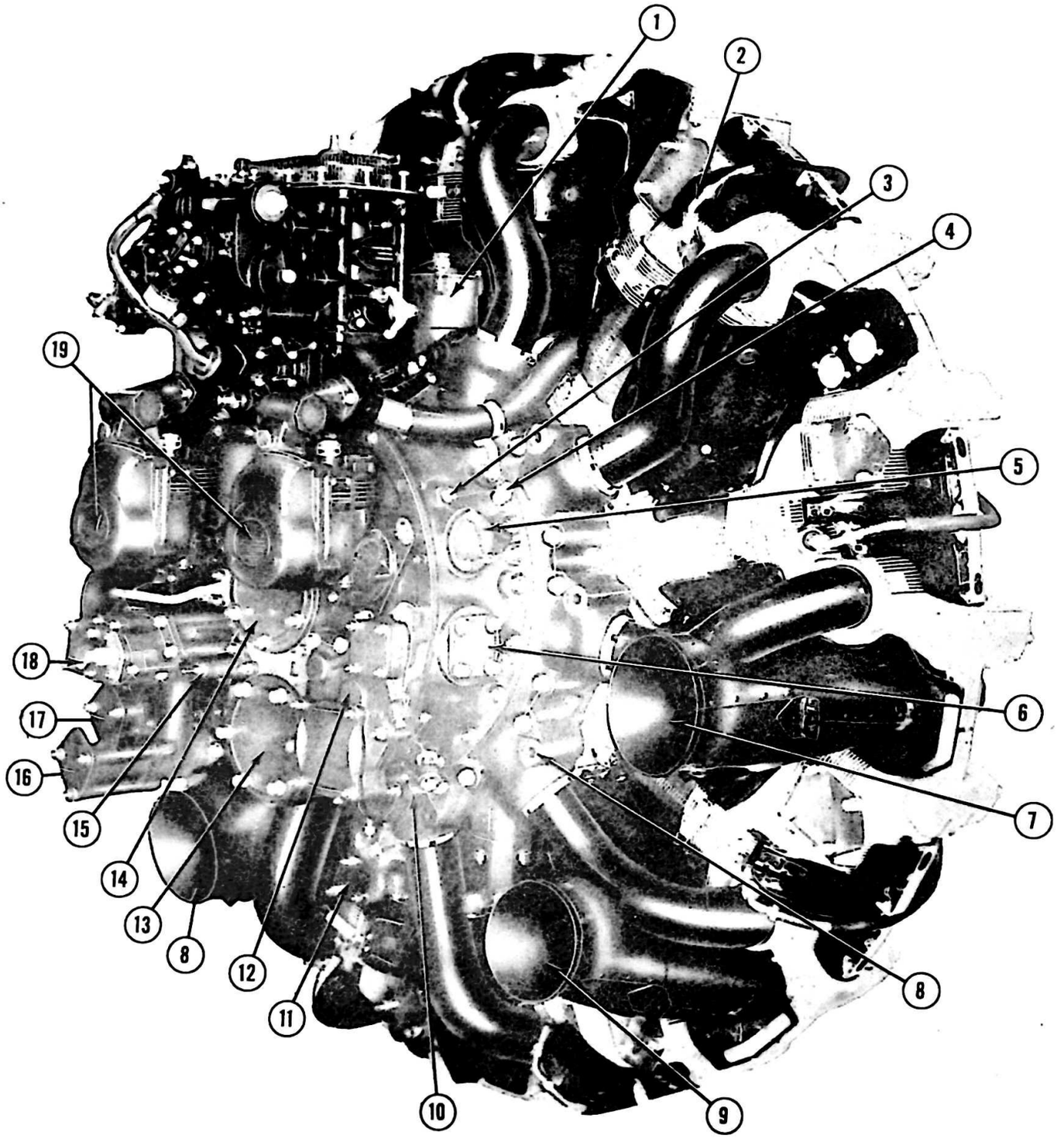
1. AIR-MAZE OIL SEPARATOR (BREATHER)
2. CARBURETOR
3. MANIFOLD PRESSURE PLUG
4. MAGNETOS
5. STARTER MOUNTING PAD
6. TACHOMETER
7. DUAL ACCESSORY DRIVE HOUSING
8. GENERATOR MOUNTING PAD
9. OIL PRESSURE RELIEF VALVE
10. OIL-OUT FLANGE
11. OIL-IN FLANGE
12. EXTERNAL SCAVENGE LINE CONNECTION (OIL PUMP)
13. EXTERNAL SCAVENGE LINE CONNECTION (OIL SUMP)
14. OIL CHECK VALVE PLUG
15. EXTERNAL HYDRO-OIL LINE
16. OIL STRAINER
17. GUN SYNCHRONIZER SUBSTITUTING COVER
18. CABIN HEATER PLUG (INTAKE)

Figure 3—Three-Quarter Left Rear View



1. CARBURETOR
2. MANIFOLD PRESSURE FITTING
3. OIL PRESSURE FITTING (MAIN OIL)
4. CARBURETOR AIR SCOOP DUCT
5. MAGNETO
6. DUAL ACCESSORY DRIVE HOUSING
7. EXTERNAL SCAVENGE LINE CONNECTION (OIL SUMP)
8. GENERATOR MOUNTING PAD
9. OIL-OUT FLANGE
10. EXTERNAL SCAVENGE LINE CONNECTION (OIL PUMP)
11. OIL COOLER DUCT
12. OIL-IN FLANGE
13. TACHOMETER
14. OIL PRESSURE RELIEF VALVE
15. EXTERNAL HYDRO-OIL LINE
16. OIL CHECK VALVE PLUG
17. TWO SPEED CLUTCH CONTROL
18. STARTER MOUNTING PAD
19. OIL TANK BREATHER CONNECTION

Figure 4—Full Rear Engine View



1. AIR-MAZE OIL SEPARATOR (BREATHER)
2. REAR SPARK PLUG TERMINAL ELBOW
3. OIL TANK VENT CONNECTION
4. CABIN HEATER CONNECTION (INTAKE)
5. RIGHT GUN SYNCHRONIZER SUBSTITUTING COVER
6. FUEL PUMP PAD
7. CARBURETOR AIR SCOOP DUCT
8. ENGINE MOUNT LUG
9. OIL COOLER AIR SCOOP DUCT
10. SUPERCHARGER DRAIN VALVE
11. EXTERNAL SCAVENGE LINE CONNECTION (SUMP)
12. DUAL ACCESSORY DRIVE HOUSING
13. GENERATOR MOUNTING PAD
14. STARTER MOUNTING PAD
15. TWO-SPEED CLUTCH CONTROL VALVE
16. OIL-OUT FLANGE
17. OIL-IN FLANGE
18. TACHOMETER
19. MAGNETOS

Figure 5—Three-Quarter Right Rear View

SECTION I

INTRODUCTION

ENGINE TYPE The Wright Cyclone 9HC engine is a 9-cylinder, single row radial, air-cooled engine, operating on the conventional four-stroke cycle. See figures 1-5. Cyclone engines of this series are equipped with one of two propeller reduction gear ratios: 3:2 or 16:9; and with a two-speed supercharger drive or a single-speed supercharger drive which may be used with an exhaust turbosupercharger.

DEFINITIONS The following terms will be used throughout this manual:

Front.....Propeller end
Rear.....Antipropeller end
Left.....As viewed facing rear of engine
Right.....As viewed facing rear of engine
Horizontal.....Position as in normal level flight
Inverted.....Upside down (carburetor toward ground)
Front End Down.....Propeller end pointing downward
Front End Up.....Propeller end pointing upward

The rotation of the crankshaft and propeller is clockwise as viewed from the rear of the engine.

The terms "Clockwise" and "Counterclockwise" with respect to the rotation of the accessory drives, refer to the observer's view when facing the accessory mounting pad on the engine.

CYLINDER NUMBERING SYSTEM The cylinders are numbered consecutively in the direction of rotation of the crankshaft, i. e., clockwise as viewed from the rear of the engine, starting with cylinder No. 1. See figure 6.

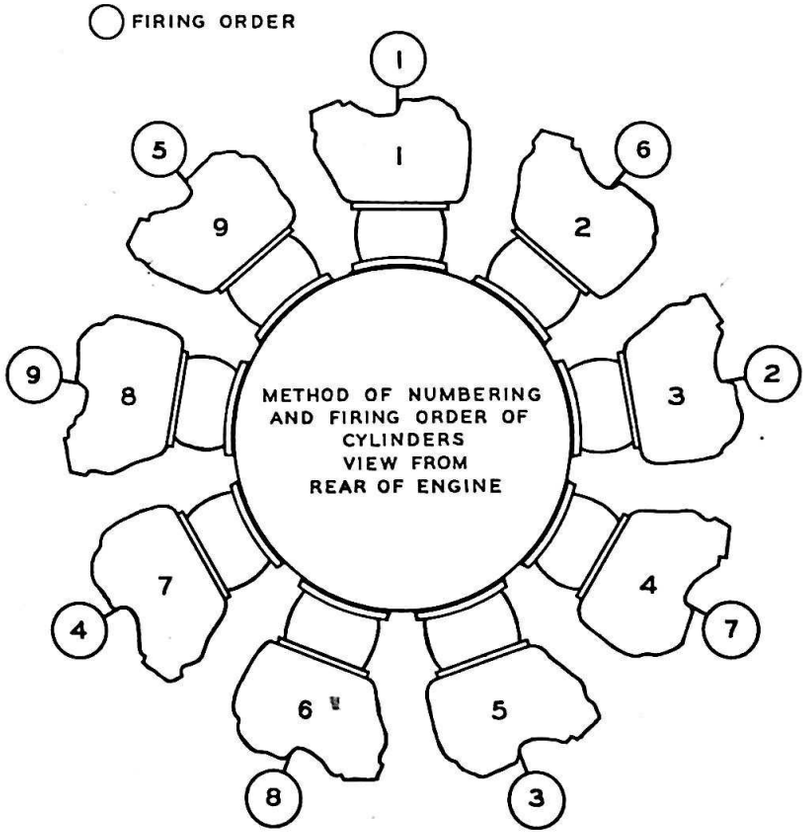


Figure 6—Cylinder Numbering and Firing Order Diagram

CYLINDER HOLD-DOWN CAP SCREWS Cylinder hold-down cap screws and cap screw holes are referred to as No. 1, 2, 3, etc. in a clockwise direction around the cylinder mounting flange. Cap screw No. 1 is the first to the right of the longitudinal center line of the cylinder at the front of the engine, with the engine in flight position. The number of the cylinder pad is the same as the number of the cylinder. See figure 7.

SYSTEMS OF MEASUREMENT All measurements throughout this manual are given in English units, and are parenthetically followed by a metric unit. The metric conversion is given for the convenience of those operators who prefer to work with that system.

INSTALLATION OF UNAPPROVED PARTS IN WRIGHT AIRCRAFT ENGINES From time to time information reaches Wright Aeronautical Corporation that engine parts which are not genuine Wright parts have been installed in Wright engines. Frequently, this practice has evidenced failure of the parts in question and these parts, after examination, proved defective in both material and workmanship. The use of parts which have not been procured from the Wright Aeronautical Corporation or through its authorized agents constitutes a misuse of the engine and voids the engine guarantee. For further details, summarizing types of released materials and accessories, refer to appendix I.

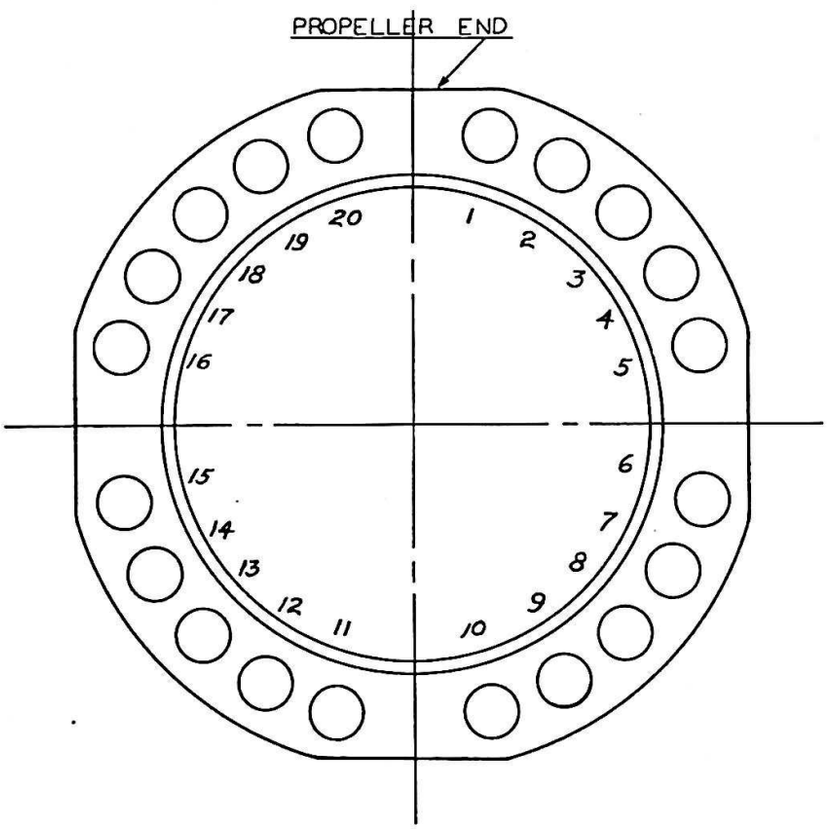


Figure 7—Cylinder Hold-Down Cap Screw Numbering Diagram

SECTION II

SPECIFICATIONS AND DESCRIPTION

TABLE OF SPECIFICATIONS

GENERAL ENGINE CHARACTERISTICS

TYPE	Static Radial, Air-Cooled, Single Row
SERIES	Wright Cyclone 9HC
MODELS	806C9HC1, 2, 3, 4, 7, and 8 805C9HC1, 2, 3, and 4 794C9HC1 and 2
NUMBER OF CYLINDERS	9
BORE	6.125 in. (155.6 mm)
STROKE	6.875 in. (174.6 mm)
PISTON DISPLACEMENT	1823 cu. in. (29.87 li)
COMPRESSION RATIO	6.55:1
IMPELLER DIAMETER	11 in. (279.4 mm)
IMPELLER GEAR RATIO	
794C9HC1 and 2 and 805C9HC1, 2, 3, and 4	7.00:1
806C9HC1, 2, 3, 4, 7, and 8	7.13:1 and 10.04:1
RATED SPEED IN RPM	2500
RATED BRAKE HP/RPM AT SEA LEVEL	1200/2500
RATED BRAKE HP/RPM AT TAKE-OFF (five minutes)	1350/2700
CRANKSHAFT ROTATION (Rear)	Clockwise
PROPELLER ROTATION (Rear)	Clockwise
PROPELLER REDUCTION GEAR RATIO	
794C9HC1 and 2, 805C9HC2 and 4	16.9 (.5625)
805C9HC1 and 3, 806C9HC1, 2, 3, 4, 7, and 8	3:2 (.666)
PROPELLER SHAFT SPLINE SIZE	SAE No. 50
MASTER ROD LOCATION	Cylinder No. 1
DIAMETER OF MOUNTING BOLT CIRCLE	23.4 in. (594.4 mm)
NUMBER OF MOUNTING BOLTS	9
DIAMETER OF MOUNTING BOLTS	.438 in. (11.12 mm)
OVERALL DIAMETER OF ENGINE	55.12 in. (1400 mm)
OVERALL LENGTH OF ENGINE	
794C9HC1 and 2	47.77 in. (1213 mm)
805C9HC1, 2, 3, and 4	46.07 in. (1170 mm)
806C9HC1, 2, 3, 4, 7, and 8	47.56 in. (1208 mm)
POSITION OF CENTER OF GRAVITY (With Accessories)	
Distance Above Center Line of Crankshaft	.20 in. (5.08 mm)
Distance Right Center Line of Crankshaft	.30 in. (7.62 mm)
Distance Aft of Thrust Nut Front Face	14.76 in. (375 mm)
Distance Forward of Rear Face of Mounting Bosses	7.40 in. (188 mm)

OPERATING LIMITS

POWER RATINGS WITH AUTO-RICH MIXTURE

Condition	BHP	RPM
Take-off (5 minutes)	1350	2700
Normal Rated	1200	2500

MAXIMUM CYLINDER TEMPERATURES

Power Condition	Head	Base
Take-off (5 minutes)	248°C (480°F)	163°C (325°F)
Normal Rated to 70% (continuous)	218°C (425°F)	149°C (300°F)
Normal Rated to 90% (1 hour)	232°C (450°F)	149°C (300°F)
Ground Operation	260°C (500°F)	163°C (325°F)

OIL TEMPERATURE

70° to 85°C (158° to 185°F) desired
90°C (200°F) normal maximum
104°C (222°F) emergency maximum

OIL PRESSURE

65 to 75 lb per sq in. (4.57 to 5.30 kg per sq cm)

VALVES AND VALVE TIMING

INTAKE OPENS—DEGREES BEFORE TOP CENTER	15
INTAKE CLOSES—DEGREES AFTER BOTTOM CENTER	44
EXHAUST OPENS—DEGREES BEFORE BOTTOM CENTER	74
EXHAUST CLOSES—DEGREES AFTER TOP CENTER	25
INTAKE REMAINS OPEN IN CRANKSHAFT DEGREES	239
EXHAUST REMAINS OPEN IN CRANKSHAFT DEGREES	279
VALVE LIFT	.562 in. (14.27 mm)
VALVE ROCKER CLEARANCES	
Cold	.010 in. (.254 mm)
Timing	.075 in. (1.91 mm)
Running (hot)	.075 in. (1.91 mm)

IGNITION SYSTEM

MAGNETO TYPE	Edison Splitdorf SF9LD-1 Edison Splitdorf SF9LD Bosch SF9LU-4, or Scintilla SF9LN-4
MAGNETO DRIVE SHAFT ROTATION (Rear)	Clockwise
MAGNETO DRIVE SHAFT SPEED RATIO TO CRANKSHAFT	1.125:1
SPARK PLUG GAP	.012 in. + .002 in. — .001 in. (.305 mm + .051 mm — .025 mm)
SPARK TIMING ON CYLINDER NO. 1	
Left Magneto (rear plugs)—degrees before top center	20
Right Magneto (front plugs)—degrees before top center	20

FUEL SYSTEM

CARBURETOR TYPE ..... Bendix Stromberg Injection PD-12-K4 or PD-12-K10

FUEL REQUIRED IN FLIGHT ..... Grade 100/130

SUPERCHARGER DRAIN VALVE CONNECTION—THREAD ..... .250 in. NP thd

FUEL INLET CONNECTION—THREAD ..... .750 in. NP thd

LUBRICATION SYSTEM

TYPE ..... Full Pressure Dry Sump

CRANKCASE VENT TO OIL TANK CONNECTION ..... .750 in. NP thd

OIL REQUIRED IN FLIGHT

- Specification ..... WAC No. 5815
- Grade 1120

ACCESSORY DRIVES AND INSTRUMENT CONNECTIONS

DUAL ACCESSORY DRIVE (UPPER)

- Mounts ..... Four .250 in.—28 US Form Studs .78 in. (19.81 mm) high, spaced 1.875 in. x 1.875 in. (47.63 mm x 47.63 mm) on pad 2.4375 in. (61.925 mm) minimum square
- Drive ..... 12-Tooth Involute Spline .600 in. (15.24 mm) pitch dia.
  - Continuous Torque ..... 50 in. lb (57.70 cm kg) maximum
  - Static Torque ..... 1200 in. lb (1384.80 cm kg) maximum
- Rotation ..... Counterclockwise
- Speed Ratio to Crankshaft 1.5:1

DUAL ACCESSORY DRIVE (LOWER)

- Mount ..... Four .313 in.—24 US Form Studs .82 in. (20.83 mm) high, equally spaced on 5 in. (127 mm) dia. circle
- Drive ..... 12-Tooth Involute Spline .600 in. (15.24 mm) pitch dia.
  - Continuous Torque ..... 150 in. lb (173.10 cm kg) maximum
  - Static Torque ..... 2250 in. lb (2596.50 cm kg) maximum
- Rotation ..... Counterclockwise
- Speed Ratio to Crankshaft 1.5:1

PROPELLER GOVERNOR

- Mount ..... Four .313 in.—24 US Form Studs .94 in. (24 mm) high, spaced 2.125 in. x 2.125 in. (53.975 mm x 53.975 mm)
- Drive ..... 12-Tooth Involute Spline .600 in. (15.24 mm) pitch dia.
  - Continuous Torque ..... 260 in. lb (300 cm kg) maximum
  - Static Torque ..... 2300 in. lb (2649 cm kg) maximum
- Rotation ..... Clockwise
- Speed Ratio to Crankshaft 1:1

FUEL PUMP DRIVE

Mount ..... Four .313 in.—24 US Form Studs
.88 in. (22.35 mm) high,
spaced 2 in. x 2 in. (50.8 mm x 50.8 mm)

Drive ..... 11-Tooth Involute Spline
.4583 in. (11.633 mm) pitch dia.

Continuous Torque ..... 16.5 in. lb (19.04 cm kg) maximum

Static Torque ..... 450 in. lb (519.30 cm kg) maximum

Rotation ..... Counterclockwise

Speed Ratio to Crankshaft 1:1

STARTER DRIVE

Mount ..... Six .375 in.—24 US Form Studs
.94 in. (23.88 mm) high,
equally spaced on 5 in. (127 mm) dia. circle

Drive ..... Twelve-Jaw Detachable Coupling
or Three-Jaw Detachable Coupling

Static Torque ..... 25,800 in. lb (29,673 cm kg) maximum

Rotation ..... Clockwise

Speed Ratio to Crankshaft 1:1

GENERATOR DRIVE

Mount ..... Six .375 in.—24 US Form Studs
.94 in. (23.88 mm) high,
equally spaced on 5 in. (127 mm) dia. circle

Drive ..... 16-Tooth Involute Spline
.800 in. (20.23 mm) pitch dia.

806C9HC1, 2, 3, 4, 7, and 8

Continuous Torque ..... 600 in. lb (692.40 cm kg) maximum

Static Torque ..... 6000 in. lb. (6924 cm kg) maximum

805C9HC1, 2, 3, and 4 and 794C9HC1, and 2

Continuous Torque ..... 230 in. lb (265.42 cm kg) maximum

Static Torque ..... 1150 in. lb (1327.1 cm kg) maximum

Rotation ..... Clockwise

Speed Ratio to Crankshaft

806C9HC1, 2, 3, 4, 7, and 8 ..... 1.500:1

805C9HC1, 2, 3, and 4 and 794C9HC1, and 2 ..... 3.274:1

TACHOMETERS

Mount

Mechanical—Connecting Thread ..... .875 in.—18 US Form

Electric ..... Four .250 in.—28 US Form Studs
.67 in. (17.02 mm) high,
spaced 1.875 in. x 1.875 in. (47.63 mm x 47.63 mm)

Drive

Mechanical ..... Key Slot

Electric ..... .250 in. (6.35 mm) Square Hole

Continuous Torque ..... 25 in. lb (28.85 cm kg) maximum

Static Torque ..... 70 in. lb (80.78 cm kg) maximum

Rotation ..... Clockwise

Speed Ratio to Crankshaft 5:1

GUN SYNCHRONIZER IMPULSE GENERATOR DRIVES (on engines so equipped)

Mount	18 Tapped Holes .250—NC-3 .63 in. (16 mm) deep equally spaced on 2.406 in. (61.11 mm) dia. circle
Drive	16-Tooth External Square Spline
Continuous Torque	4 in. lb (4.62 cm kg) maximum
Static Torque	150 in. lb (173.10 cm kg) maximum
Rotation	
Left	Clockwise
Right	Counterclockwise
Speed Ratio to Crankshaft	Same as Propeller Gear Ratio

OIL PRESSURE GAGE CONNECTION	.125 in. NP thd
FUEL PRESSURE GAGE CONNECTION	.125 in. NP thd
MANIFOLD PRESSURE GAGE CONNECTION (restriction incorporated)	.125 in. NP thd
COMBUSTION TYPE HEATER, INLET CONNECTION	.250 in. NP thd
INSTRUMENT OR COMBUSTION TYPE HEATER, EXHAUST CONNECTION	.625 in.—18 US Form

ACCESSORY AND ENGINE WEIGHTS

ACCESSORY WEIGHTS

Carburetor and Adapter	43.50 lb (19.74 kg)
Carburetor Screens and Gaskets	1.50 lb (.6704 kg)
Magnetos	20 to 35 lb. (9.07 to 15.87 kg)
Ignition Harness and Cable Assembly	20 lb (9.07 kg)
Spark Plugs (per set)	3 to 5 lb (1.36 to 2.27 kg)
Priming System	2 lb (.907 kg)
Cylinder Air Deflectors	20 lb (9.07 kg)
Accessory Drive Covers	2 lb (.907 kg)

TOTAL DRY WEIGHT OF ENGINE

806C9HC1	1333 lb (606 kg)
805C9HC1	1315 lb (598 kg)
794C9HC1	1330 lb (605 kg)

SPECIAL ACCESSORY WEIGHTS

Torquemeter	5 lb (2.27 kg)
Two Intercylinder Duct Deflectors	5.125 lb (2.384 kg)
Four Intercylinder Duct Deflectors	10.250 lb (4.768 kg)

DOMESTIC SHIPPING BOX (approximate)	725 lb (328 kg)
TOOL KIT	18 lb (8.16 kg)
LIFTING CABLE ASSEMBLY	3.25 lb. (1.47 kg)

DIFFERENCES BETWEEN MODELS

	806C9HC1	806C9HC2	806C9HC3	806C9HC4	806C9HC7	806C9HC8
Torquemeter	Non-Torque	Torquemeter	Non-Torque	Torquemeter	Non-Torque	Torquemeter
Propeller Reduction Gear Ratio	3:2	3:2	3:2	3:2	3:2	3:2
Impeller Gear Ratio	7.134:1 and 10.04:1	7.134:1 and 10.04:1	7.134:1 and 10.04:1	7.134:1 and 10.04:1	7.134:1 and 10.04:1	7.134:1 and 10.04:1
Magnetos	Compensated Edison-Splitdorf SF9LD-1 or Scintilla SF9LN-4	Compensated Edison-Splitdorf SF9LD-1 or Scintilla SF9LN-4	Compensated Edison-Splitdorf SF9LD-1	Compensated Edison-Splitdorf SF9LD-1	Compensated Edison-Splitdorf SF9LD-1	Compensated Edison-Splitdorf SF9LD-1
Carburetor	Stromberg PD-12-K4 or PD-12-K10	Stromberg PD-12-K10	Stromberg PD-12-K10	Stromberg PD-12-K10	Stromberg PD-12-K10	Stromberg PD-12-K10
Intercylinder Air Deflectors	9 Standard or 5 Standard and 4 Duct Deflectors	9 Standard or 5 Standard and 4 Duct Deflectors	7 Standard and 2 Duct Deflectors	7 Standard and 2 Duct Deflectors	5 Standard and 4 Duct Deflectors	5 Standard and 4 Duct Deflectors
Gun Synchronizer Drives	No Drives Supplied	No Drives Supplied	Two Drives	Two Drives	No Drives Supplied	No Drives Supplied
Engine Breather	Crankcase with Air-Maze Oil Separator	Crankcase with Air-Maze Oil Separator	Crankshaft	Crankshaft	Crankcase with Air-Maze Oil Separator	Crankcase with Air-Maze Oil Separator

DIFFERENCES BETWEEN MODELS (Continued)

	805C9HC1	805C9HC2	805C9HC3	805C9HC4	794C9HC1	794C9HC2
Torquemeter	Provision for Torquemeter	Provision for Torquemeter	Torquemeter	Torquemeter	Non-Torque	Torquemeter
Propeller Reduction Gear Ratio	3:2	16:9	3:2	16:9	16:9	16:9
Impeller Gear Ratio	7.00:1	7.00:1	7.00:1	7.00:1	7.00:1	7.00:1
Magnetos	Compensated Supercharged Edison-Splitdorf SF9LD	Compensated Supercharged Edison-Splitdorf SF9LD	Compensated Supercharged Edison-Splitdorf SF9LD	Compensated Supercharged Edison-Splitdorf SF9LD	Compensated Supercharged American Bosch SF9LU-4	Compensated Supercharged American Bosch SF9LU-4
Carburetor	Stromberg PD-12-K4 or PD-12-K10	Stromberg PD-12-K10	Stromberg PD-12-K10	Stromberg PD-12-K10	Stromberg PD-12-K4 or PD-12-K10	Stromberg PD-12-K10
Intercylinder Air Deflectors	3 Standard 6 Duct Deflectors	1 Standard 8 Duct Deflectors	3 Standard 6 Duct Deflectors	1 Standard 8 Duct Deflectors	9 Standard	9 Standard
Gun Synchronizer Drives	Two Drives	Two Drives	Two Drives	Two Drives	Provision for One Drive	Provision for One Drive
Engine Breather	Crankcase with Air-Maze Oil Separator	Crankcase with Air-Maze Oil Separator	Crankcase with Air-Maze Oil Separator	Crankcase with Air-Maze Oil Separator	Crankcase with Breather Flange	Crankcase with Breather Flange

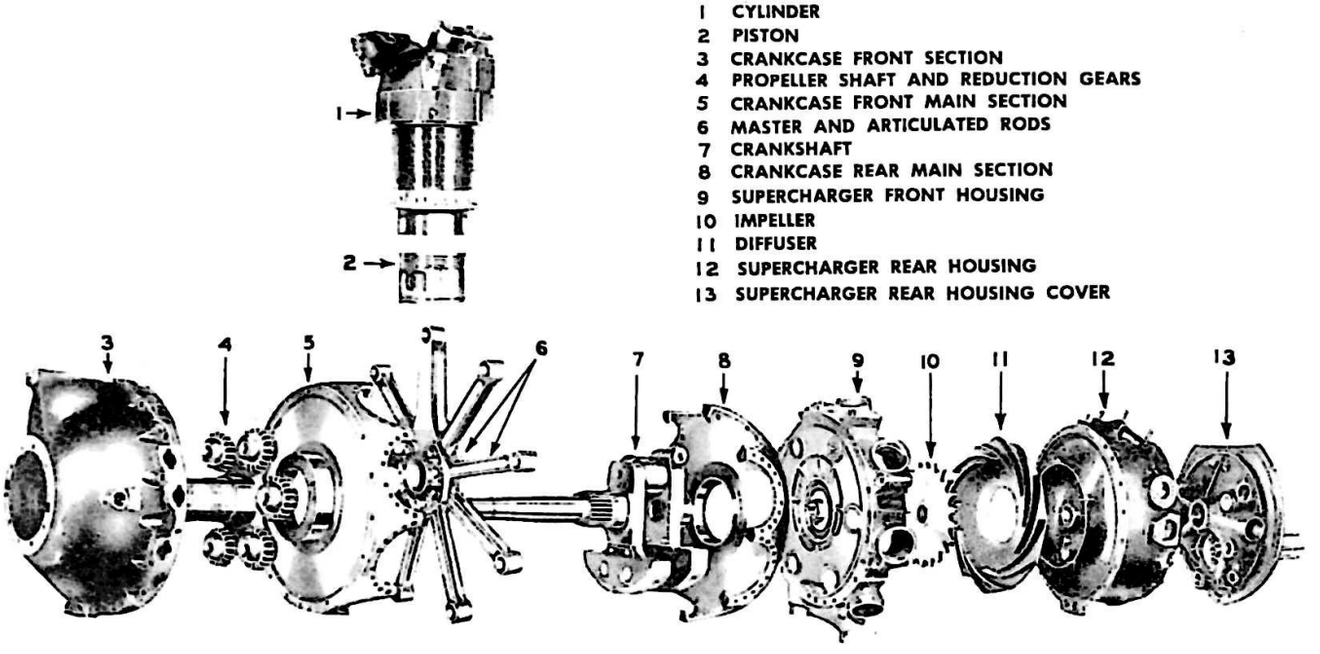


Figure 8—Exploded View of All Sections

FRONT SECTION

The crankcase front section, a magnesium alloy casting, houses the propeller shaft and reduction gear assembly and the valve tappets and guides. See figure 9.

PROPELLER SHAFT AND REDUCTION GEAR The propeller shaft is threaded to receive the thrust nut and splined to receive the propeller hub. Provision is made for a hydromatic or electric propeller. Propeller shaft thrust is absorbed by a ball bearing iocated in the front of the crankcase front section.

Reduction gearing is of the planetary type. The reduction driving gear is splined to the crankshaft and drives the planetary pinions. The rotation of these pinions around the stationary reduction gear drives the propeller shaft.

The shaft for the .666 (3:2) reduction gear ratio engine has six pinion arms forged integrally at the rear end. The end of each arm is fitted with bronze bushings which carry the reduction gear pinions.

The shaft for the .5625 (16:9) reduction gear ratio has a large flange forged integrally at the rear end. A carrier ring is fastened to the flange and incorporates 20 trunnions, each of which supports a bushing and pinion.

PROPELLER GOVERNOR DRIVE A propeller governor intermediate drive is supported in a bushing at the top of the crankcase front section, and a mounting pad directly above this drive provides for a propeller governor.

The propeller governor intermediate drive gear takes its drive from the propeller governor drive gear bolted to the front face of the cam intermediate drive gear.

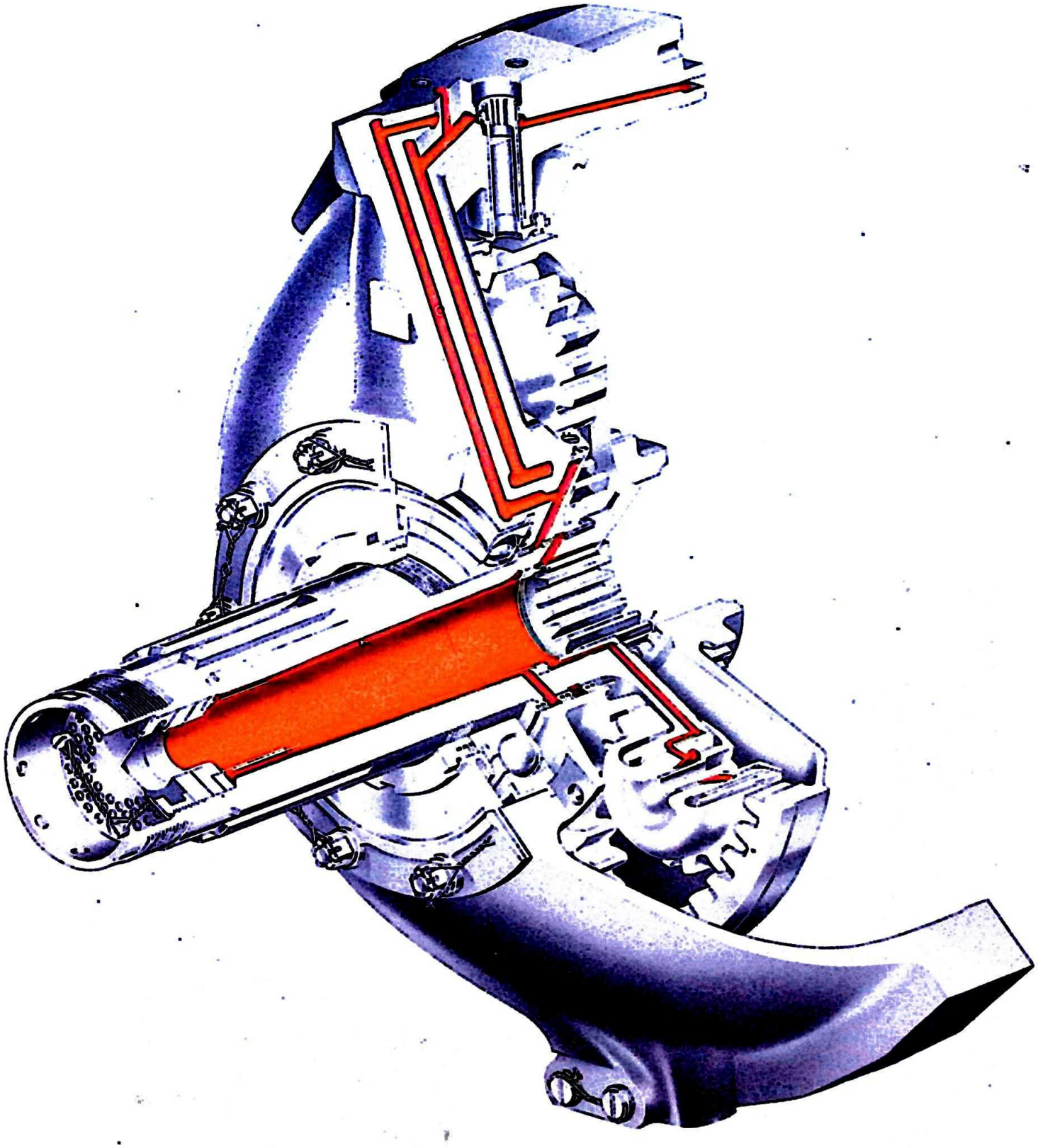


Figure 9—Cutaway View of Front Section

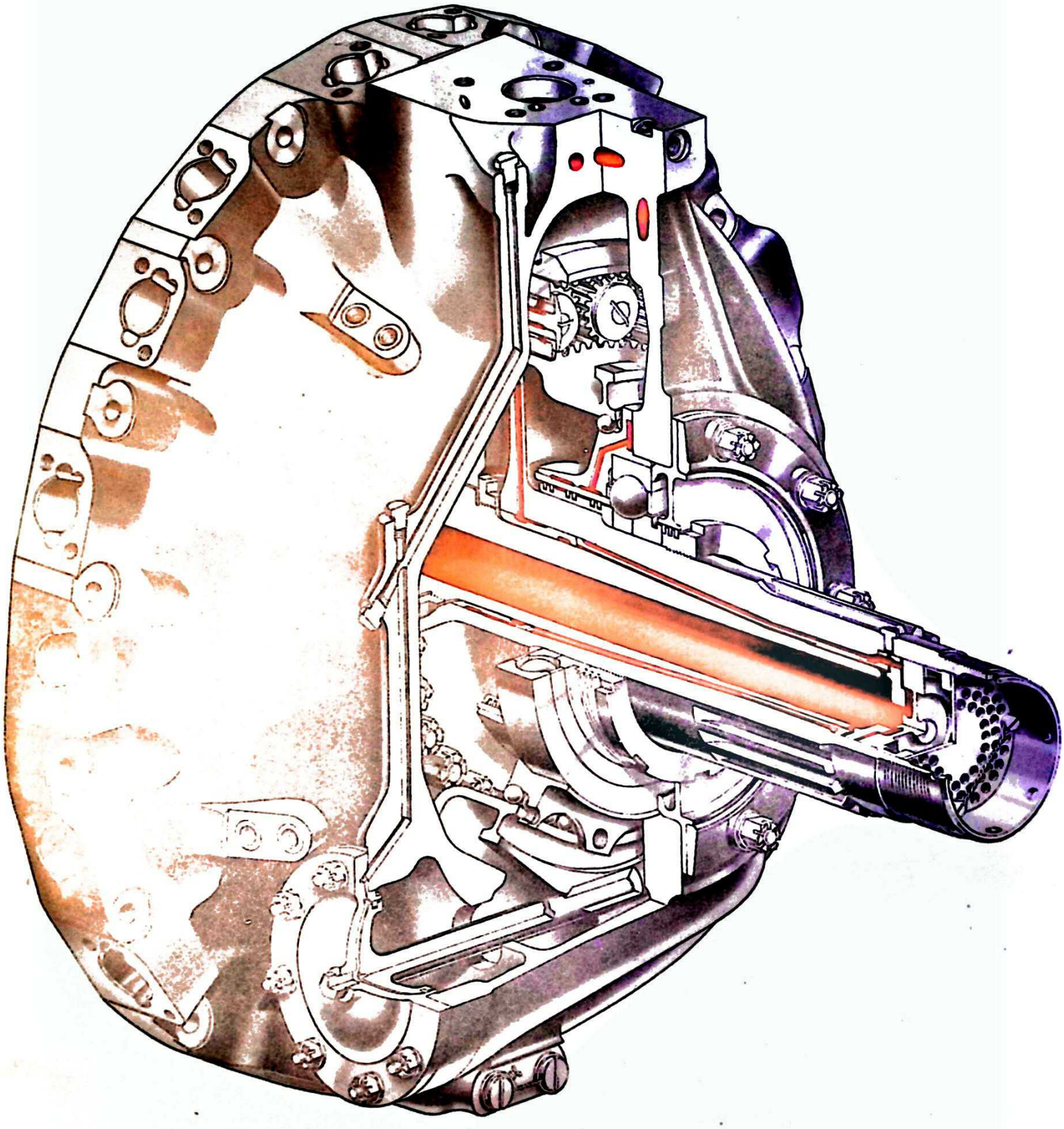


Figure 10—Cutaway View of Front Section with Torquemeter

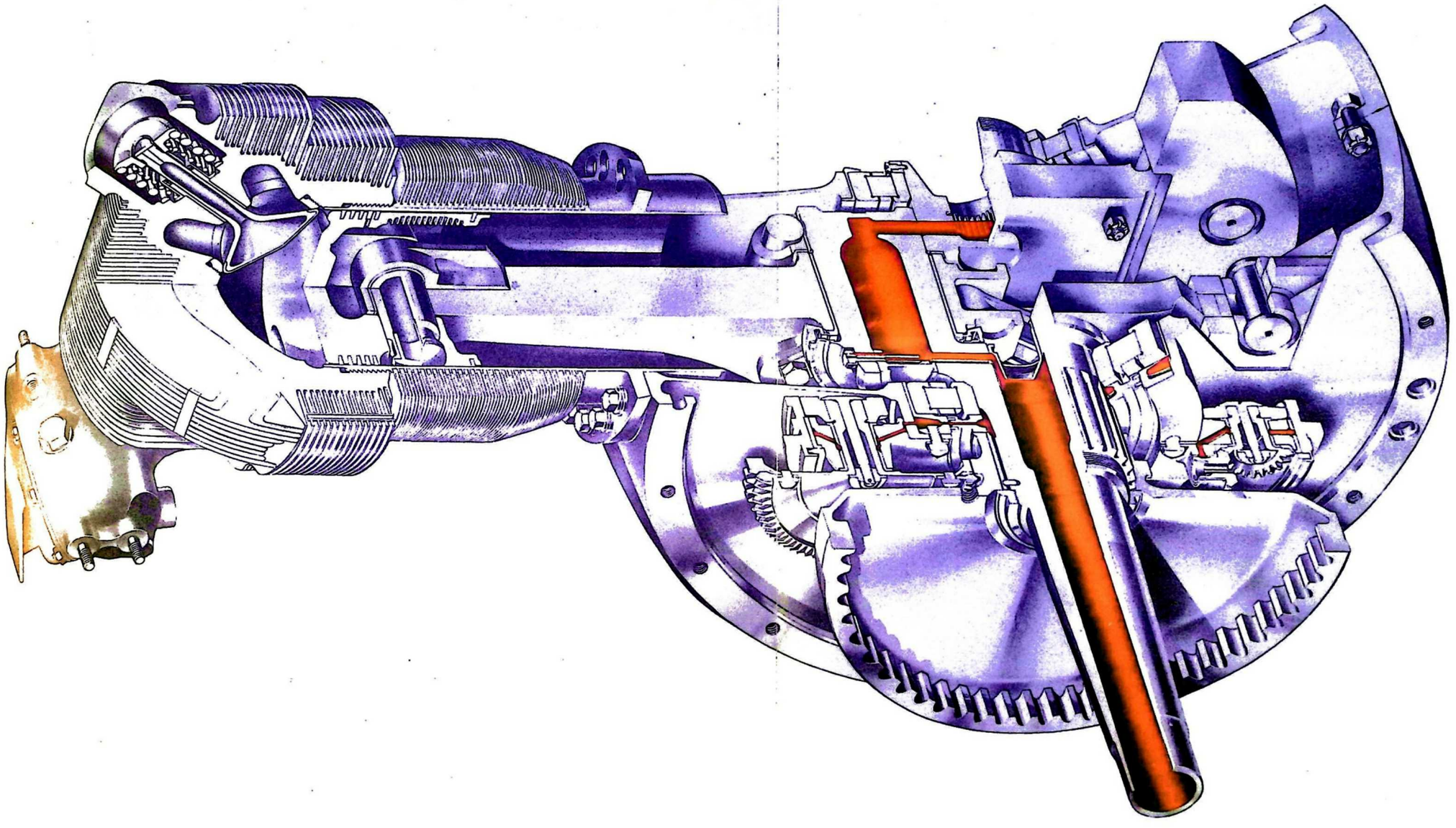


Figure 11—Cutaway View of Main Section

TORQUEMETER When the torquemeter is used, the crankcase front section is cast with an integral torquemeter housing located at the bottom. The torquemeter measures the torque reaction of the floating stationary gear in the propeller reduction gearing. This stationary gear has a ball race on its inside circumference, and an integral torque arm. An adapter bolted to the crankcase front section has a similar ball race on its outside circumference. The races are provided with 35 bearing balls alternating with 35 spacer balls of a smaller diameter which act as an antifriction agent. See figure 10.

The outer end of the torque arm supports and acts on a balancing valve enclosed in the torquemeter housing. The valve is actuated in one direction by the torque reaction of the floating stationary gear and is balanced in the other direction by oil pressure on the valve head. The entire oil displacement of a small high pressure oil booster pump is conducted through cored passages to the torquemeter valve housing. The booster pump is installed on the propeller governor mounting pad and the governor is mounted above it. The floating stationary gear is kept from rotating beyond its limit at one end by a stationary stop in the front section and at the other end by oil pressure acting on the head of the valve.

When the engine is operating, the torque reaction of the floating stationary gear causes a slight outward movement of the valve and an increase in the oil pressure on the valve head. Two oil drain slots in the cover, in which the valve moves, are covered by the valve until the booster pump builds up sufficient oil pressure to overcome the torque reaction and produces slight inward movement of the valve. This inward movement of the valve partly opens these slots, allowing oil to drain into the crankcase. The oil pressure on the head of the valve decreases until the torque reaction again is just sufficient to overcome the oil pressure and another slight outward movement of the valve is produced. This cycle is repeated until a point of equilibrium is reached.

An oil pressure gage line is tapped into the valve housing cover at the valve head and leads to a special oil pressure gage calibrated to indicate brake mean effective pressure in pounds per square inch.

SUMP The sump, an aluminum casting, is of irregular shape as required to fit between cylinders No. 5 and 6. The forward part of the sump is attached to the crankcase front section and the rear two arms are attached to the supercharger front housing. The sump is kept nearly dry in normal operation by the pump located in the sump which pumps the oil back through an external oil scavenge line to a "Y" connection at the rear of the oil pump. This oil sump pump takes its drive from the cam mechanism. A magnetic drain plug screwed into the bottom of the sump traps any foreign ferrous particles. An oil screen strainer is held in place by the plug.

MAIN SECTION

The main section of the crankcase consists of two alloy steel forgings which are parted at the cylinder center line.

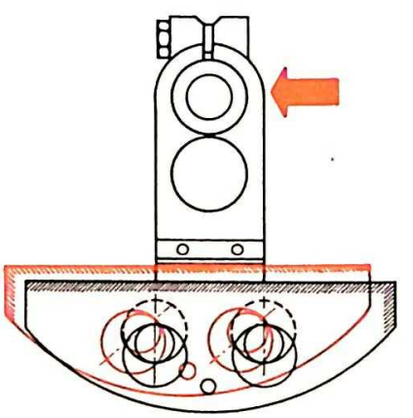
The crankcase main section houses the crankshaft and provides mounting pads for the nine cylinders. A hub in this section is extended at the center of the front diaphragm to receive the cam bearing support and cam. The roller bearings are assembled in steel bearing retainer rings which are shrunk into the front and rear diaphragms. See figure 11.

CRANKSHAFT The two-piece single-throw crankshaft is supported in the crankcase by two demountable roller bearings.

The crankshaft front section includes the crankshaft front extension, front dynamic damper counterweight, and the crankpin. The crankshaft front extension is plugged at the crank cheek. In engines which breathe through the crankshaft, this plug is replaced by a breather tube support.

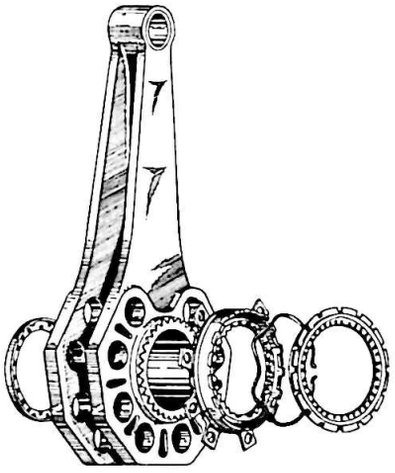
The crankshaft rear section includes the crankshaft rear crank cheek, rear dynamic damper counterweight, and crankshaft rear extension. The rear crank cheek is the split clamp type.

The dynamic damper counterweight is a short pendulum hung on the crankshaft and tuned to the frequency of the



power impulses to absorb vibration. Each unit consists of a counterweight supported on two floating pins which pass through the extended portion of the crank cheek. The component parts of the dynamic damper assemblies are locked to the crankshaft by stops bolted to the crank cheeks. The stops also limit the movement of the damper weights when the crankshaft is rotated slowly and prevent the pins from falling out. When the crankshaft is rotated slowly by hand, the noise made by the action of the counterweight, when passing top center position, is in some cases clearly discernible. This information is brought to the attention of operators in order to prevent unnecessary investigation to determine the source of this noise.

CONNECTING ROD ASSEMBLY The connecting rod assembly consists of a master rod which operates in cylinder No. 1, and eight articulated rods attached to the master rod by knuckle pins. The knuckle pins are of the floating type. All connecting rods are of the H-section type.



The front end-seal assembly consists of a knuckle pin lock plate, a spring, and oil seal disk. The lock plate is bolted to the forward end of each knuckle pin and splines into the forward end of the loose prefit silver-plated master rod bearing. A perforated oil seal spacer fits over a boss on the rear side of the master rod.

PISTONS The forged aluminum alloy pistons are the full trunk type with flat tops. Each piston employs six ring grooves, five above the piston pin bore and one below it. The top three grooves are tapered slightly and a wedge-type ring is assembled in each. The three lower ring grooves are of rectangular cross section. Oil control holes are drilled in the fourth and fifth grooves.

Engines equipped with the single simplex assembly have a single taper, wedge-shaped compression ring in grooves No. 1, 2, and 3. No. 1 ring is chrome plated. Groove No. 4 employs six piston ring parts: one spacer, two expanders, and three oil control rings. Grooves No. 5 and 6 employ standard rectangular piston rings with No. 6 installed in the inverted position. See figure 12.

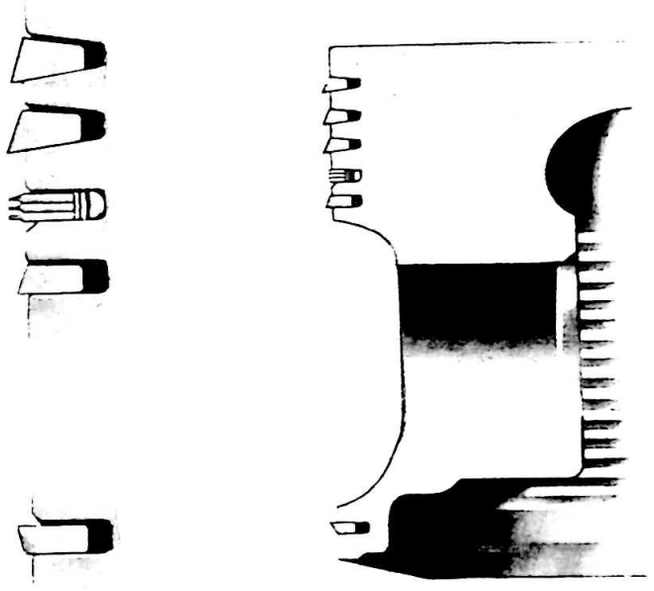


Figure 12—Simplex Piston Ring Arrangement

The piston pins float in the articulated rod bushings and in the pistons. Plug type retainers fit at each end of the piston pin and hold it in place but do not interfere with the floating design. There are three holes in each plug that prevent pressure building up within the piston pin and plug. See figure 13.

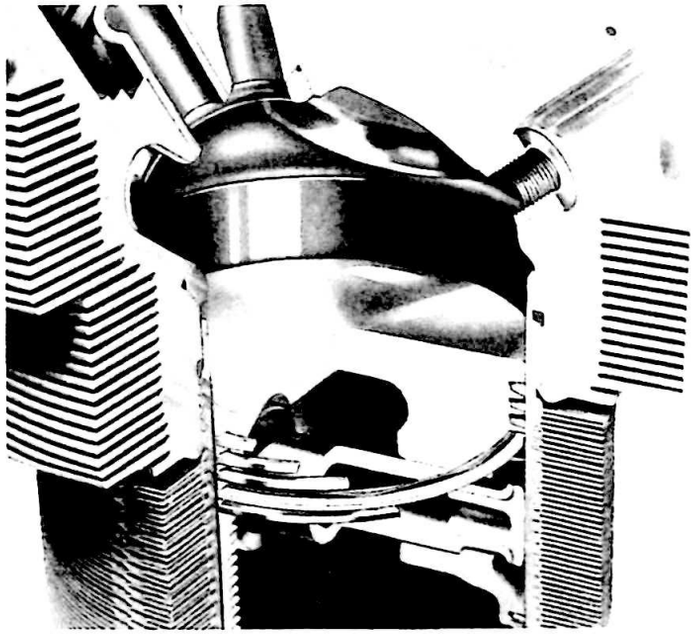


Figure 13—Cutaway View of Cylinder and Piston

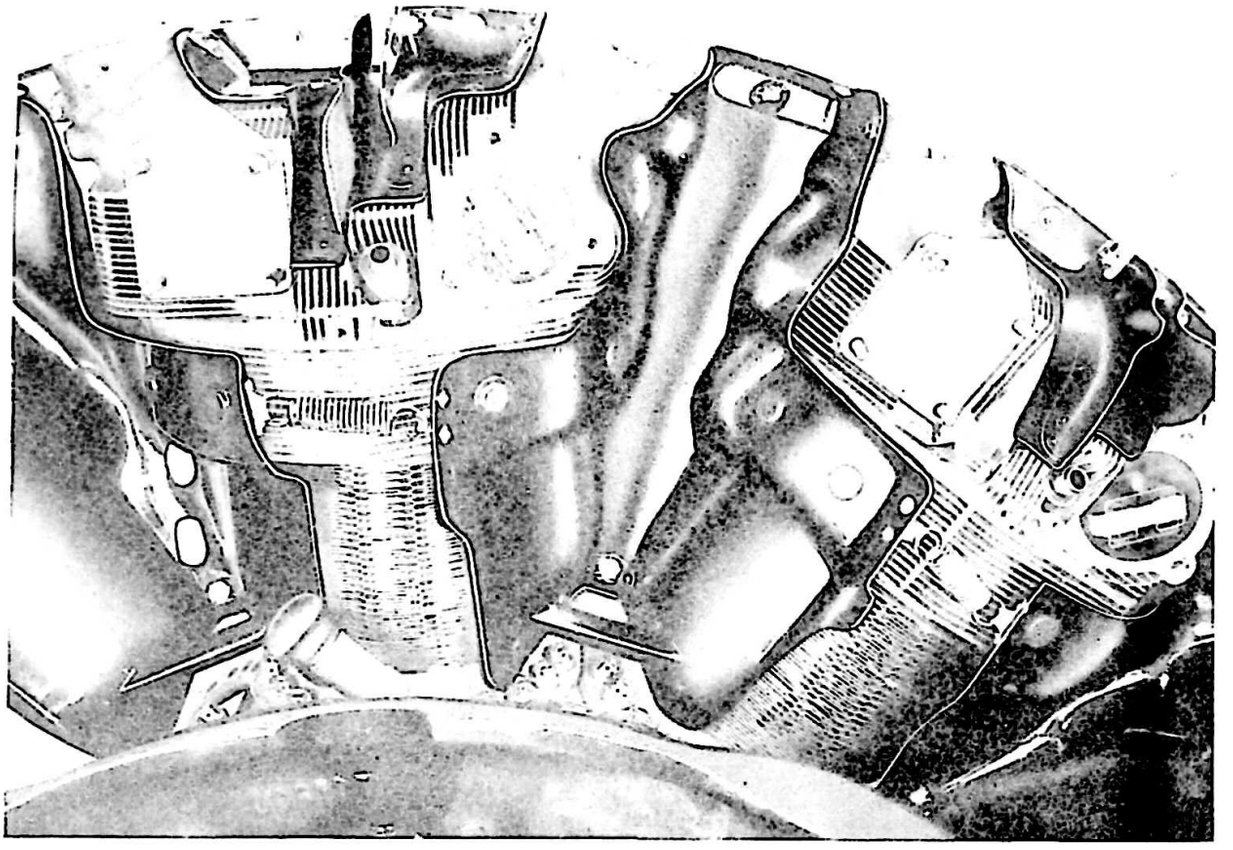


Figure 14—Head and Intercylinder Air Deflectors

CYLINDERS The cylinders are built up of forged aluminum heads shrunk and screwed on steel barrels having aluminum fins. The aluminum fins are of the "W" type and are pressed in and crimped. These fins provide high cooling efficiency. Twenty holes, in series of five, are provided in the bolting flange for the cap screws, which secure the cylinder assembly to the engine crankcase.

The intake valve seat is shrunk into the dome of each cylinder head. The exhaust valve seat is the floating type and is screwed into the dome of each cylinder head. The top of the exhaust valve guide is fitted with two oil seal rings, two spacers, and their retainer. High exhaust ports provide for excellent scavenging of exhaust gases. A detonation indicator pick-up boss is incorporated at the front of the cylinder head just above the horizontal fins. A temperature indicator boss is located at the rear of the cylinder head.

The rocker boxes are machined to accommodate rocker arms and each is provided with six studs for securing the aluminum rocker box cover. A boss at the front and rear of each intake rocker box locates two studs for cowl attachment.

INTAKE PIPES The intake pipes are secured by packing nuts to tapped holes in the supercharger front housing and their flanged end is attached to the cylinder intake port at the right of the cylinder head.

AIR DEFLECTORS Cylinder head air deflectors and intercylinder air deflectors are the pressure type and are close fitting. See figure 14. Some of the engines in this series are equipped with two, four, six, or eight intercylinder duct deflectors. These deflectors provide cooling air for oil coolers and turbo inter-coolers, and air for the carburetor airscoop. An airscoop is secured to the front of the duct type deflector.

CAM Four approximately one-quarter circle brackets secure the cam to its support on the forward wall of the crankcase front main section. A bushing at the top of the support provides for the cam intermediate drive gear and pinion; and a bushing at the bottom of the support provides for an oil sump scavenge pump drive

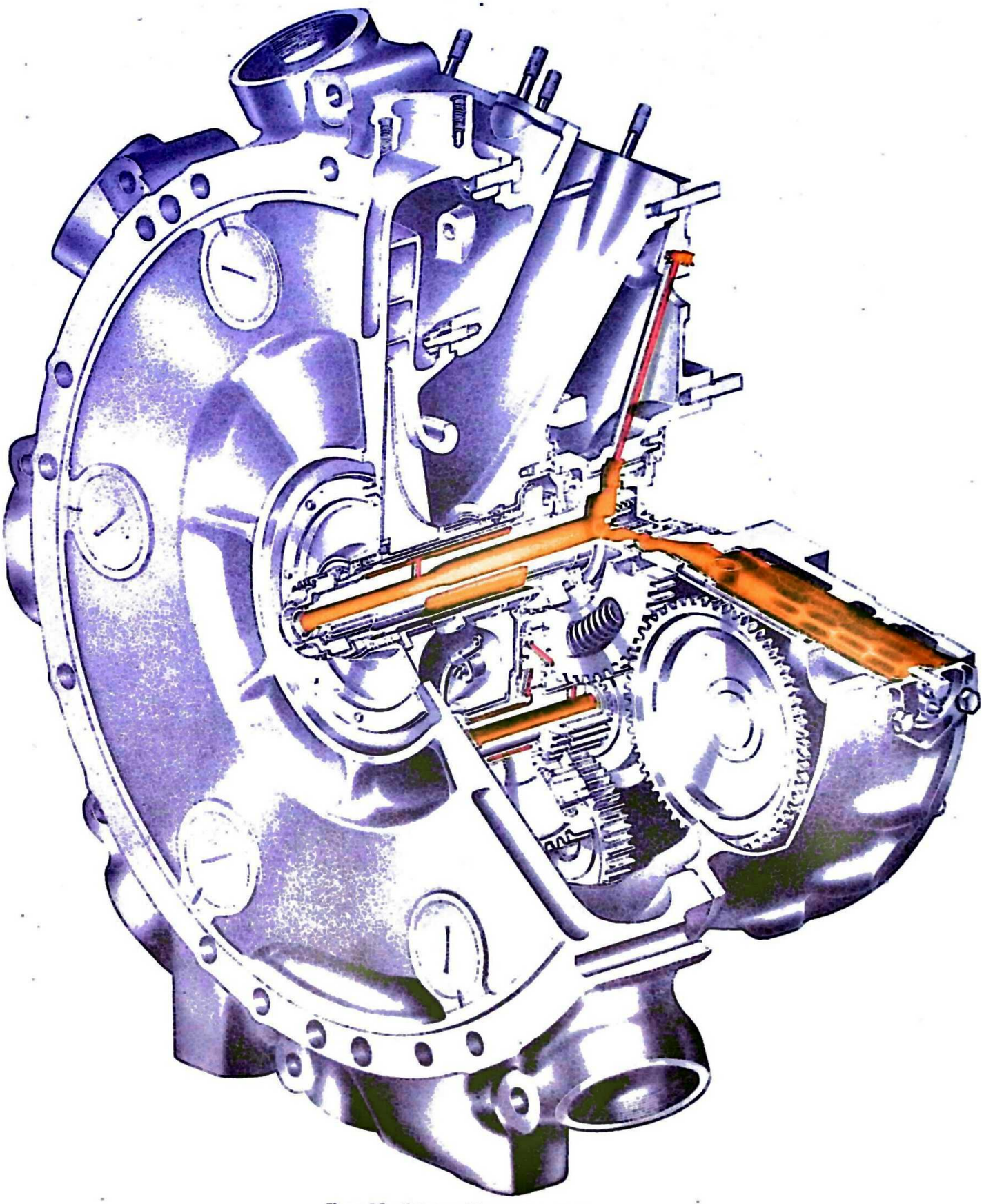


Figure 15—Cutaway View of Rear Section

gear and pinion. The drive is from the gear at the rear of the reduction driving gear, to the cam intermediate drive gear and pinion, to internal teeth at the rear of the cam rim. These internal cam teeth drive the oil sump pump scavenge drive pinion and gears.

The cam, which is internally driven in a counterclockwise rotation, consists of a hardened steel ring having an intake and an exhaust track with four lobes on each track. Tappets which ride on the cam tracks actuate poppet valves through interconnecting push rod and rocker arms.

VALVES - The heat resisting steel intake and exhaust valves are mushroom-shaped. Both valve stems and heads are hollow and partially sodium filled. The exhaust valve stem is larger in diameter than the intake valve stem. Two concentric high frequency valve springs are secured to the stem of each valve by a split lock and a shouldered steel retaining washer.

REAR SECTION

The "REAR SECTION" referred to in this section is comprised of the supercharger front housing, supercharger rear housing, and supercharger rear housing cover. See figure 15.

SUPERCHARGER FRONT HOUSING The supercharger front housing, a magnesium alloy casting, forms the forward wall of the diffuser section and distribution chamber and provides a breather passage for engines that breathe through the crankcase. Cored holes in the bottom of the housing form drainage and breathing passages to the oil sump. The supercharger front housing has nine mounting lugs for supporting the engine and nine tapped bosses for intake pipe connections.

SUPERCHARGER REAR HOUSING The supercharger rear housing, a magnesium alloy casting, forms the rear wall of the diffuser section, provides the induction passage to the impeller, and houses the accessory drive gears. The vaned type diffuser plate is attached to the front face of the diaphragm, where it shrouds the impeller. A removable oil strainer is attached to the left side of the supercharger rear housing and seats near the center of the supercharger rear housing cover. Two gun synchronizers or substituting covers with integral plugs, a fuel pump, and an oil screen strainer are mounted on the sides of this section.

SUPERCHARGER REAR HOUSING COVER The supercharger rear housing cover, a magnesium alloy casting, provides mounting pads for the two magnetos, generator, starter, oil pump, two-speed clutch control, and dual accessory drive housing. Accessory drive shafts and the rear journal of the accessory drive and starter shaft ride in bushings in the front face of the cover.

ACCESSORY DRIVE MECHANISM The impeller and all the accessory drive shafts are driven by a spring-loaded gear at the rear of the accessory drive and starter shaft. This shaft takes its drive from the crankshaft rear extension.

The journals of the accessory gears rotate in bushings pressed in bosses on the supercharger rear housing cover. The generator drive gear meshes with the impeller intermediate drive gear of the two-speed supercharger engines, or with the corresponding pinion gear of the single-speed assembly. Either of these gears, in turn, is driven by the accessory drive and starter shaft gear. Both the oil pump and the fuel pump-dual accessory drive gears are dual with the larger gear of each meshing with the accessory drive and starter shaft gear and each of the smaller gears mating with a magneto drive gear. The gun synchronizer drive gears, when used, mesh with spiral gear teeth cut into the magneto drive shafts. On engines not equipped with gun synchronizer drives, substituting covers with integral plugs replace the gun synchronizer drive shaft supports. A fuel pump drive gear meshes with a spiral gear cut in the fuel pump-dual accessory drive shaft.

DUAL ACCESSORY DRIVE—A dual accessory drive housing mounted on the supercharger rear housing cover is provided for optional accessory drives. The main drive gear is integral with a shaft which splines with the fuel pump and dual accessory drive shaft. The main drive gear referred to as the dual accessory drive intermediate gear meshes with a rear idler gear to make up the primary gear train of the unit. The second train of gears, identified by their smaller teeth, consists of a front idler gear bolted to and turning with the rear idler gear and meshing with upper and lower accessory drive gears.

TACHOMETER DRIVES—Provision is made at the rear end of the oil pump for two tachometer drives, one mechanical and one electrical. The tachometer drives are effected by a small drive shaft which is splined to the pressure oil pump drive shaft. The extended type tachometer drive is mechanical and the flange type is electrical.

SUPERCHARGER The supercharger, which is of the centrifugal type, consists of an impeller or blower, diffuser plate, and distribution chamber. The impeller is mounted on a hollow steel shaft concentric with the accessory drive and starter shaft. The distribution chamber surrounds the impeller and the diffuser plate. The impeller operates with the inlet side facing the rear of the engine.

Two oil seal sleeves, one on either side of the impeller, carry oil seal rings which ride within supports contained in the front and rear supercharger housing diaphragms. A vent from the front oil seal sleeve is led to the rear oil seal sleeve by means of two blind splines on the impeller shaft to relieve differentials in pressure. The rear oil seal sleeve, in turn, is vented to the atmosphere.

A drain passage and valve are provided at the lower rear portion of the supercharger induction passage to prevent the accumulation of excess fuel. Engines not equipped with a turbosupercharger use a standard drain valve. See figure 60. Turbosupercharged engines use a similar valve of slightly different construction. See figure 16.

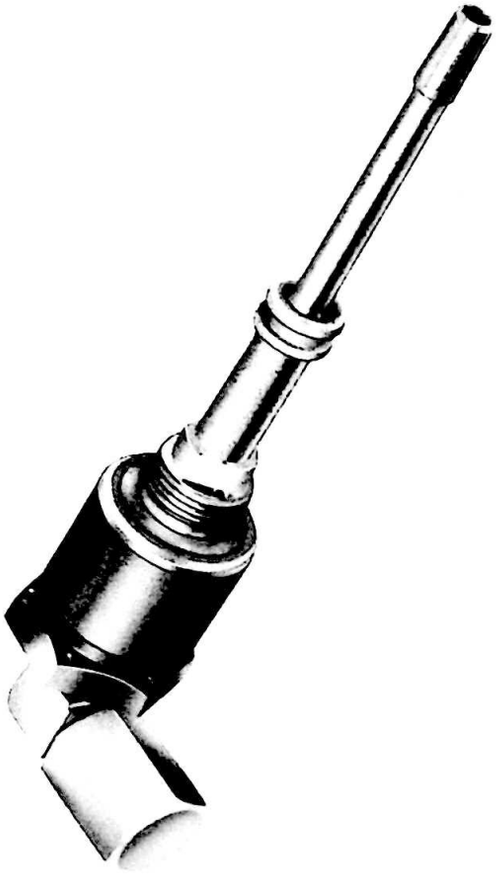


Figure 16—Turbosupercharger Drain Valve

SINGLE-SPEED SUPERCHARGER — The single-speed supercharger drive unit consists of an impeller drive gear and pinion integral with a shaft. The drive for the impeller is from the accessory drive gear to the impeller drive gear and pinion, to the impeller shaft gear. The single-speed supercharger drive engine may be used with an exhaust driven turbosupercharger.

TWO-SPEED SUPERCHARGER—The roller clutch two-speed supercharger drive is a small compact unit located in the supercharger rear housing.

The clutch is controlled by a push-pull selector valve in the supercharger rear housing cover which connects corresponding oil passages to provide oil pressure behind the hydraulic multi-plate clutch piston or to cause this oil to drain. When the hydraulic multi-plate clutch is engaged, it holds the impeller intermediate drive shaft stationary, causing the planetary gear drive to become effective, thereby producing high speed operation. When the hydraulic multi-plate clutch is disengaged, supercharger operation is effected through the cam and roller assembly which locks all movable parts of the clutch and causes it to turn as a unit, resulting in a drive similar to the single-speed supercharger drive.

In low ratio the drive is effected by a wedging action of the two races of the roller unit. In high ratio the drive is effected by friction through hydraulic pressure action on the clutch plates.

CARBURETION

Carburetion is supplied by a Stromberg injection carburetor, PD-12K4 or PD-12K10. Refer to the table of Differences between Models in this section.

TWO-POINT PRIMING SYSTEM An electric solenoid operated priming valve mounted on the carburetor fuel pressure regulator unit controls the flow of fuel when the engine is being primed. The fuel is then discharged from a tee connection into two priming tubes. These tubes lead to nozzles at each side of the carburetor adapter. The priming charge is thus directed into the induction passage.

IGNITION

MAGNETOS Engines in this series may be equipped with Edison-Splitdorf SF9LD, Edison-Splitdorf SF9LD-1, American Bosch SF9LU-4, or Scintilla SF9LN-4 magnetos. Refer to the table of Differences between Models in this section. All magnetos employed in this series are compensated and those used with single-speed engines are supercharged.

IGNITION CABLE HARNESS A radio-shielded ignition cable harness conducts the ignition cables from the magneto outlets to the front and rear spark plugs of each cylinder. The ignition cable manifold extends around the outside of the crankcase front section at the parting surface.

LUBRICATION

The lubrication system is the full pressure, dry sump type.

OIL PUMP Oil is fed to the oil pump from the external supply tank. It is returned to this tank by scavenge gears in the oil pump and the oil sump pump. Oil enters the inlet side of the pump, enters the pressure gear chamber at the rear side of the pump, and is delivered into an annulus at the oil inlet check valve location. From this annulus, oil is bypassed through the pressure relief valve or delivered through cored and drilled passages in the supercharger rear housing cover, through the oil strainer and into the annulus around the starter shaft bushing. See figure 17.

PRESSURE RELIEF VALVE—When the predetermined pressure set by the valve spring tension is exceeded, some oil is bypassed through the pressure relief valve and returned to the inlet passage of the oil pump.

OIL INLET CHECK VALVE—On engines equipped with an oil inlet check valve, the spring tension keeps the valve closed against the ports in the annulus when the engine is stopped, preventing leakage of oil from the tank into the engine when the engine is standing idle; or uncovers these ports when the engine is running, allowing the oil to enter the supercharger rear housing cover.

OIL STRAINER After passing through the supercharger rear housing cover, the oil fills an annular chamber surrounding the oil strainer and is forced into the hollow center of the strainer through the wire mesh screen. In the event the oil strainer is clogged or the oil is of high viscosity, a pressure relief valve opens and the oil bypasses the oil strainer. From the oil strainer, oil is delivered to the annulus surrounding the accessory drive and starter shaft.

ACCESSORY DRIVE AND STARTER SHAFT ANNULUS Four ribbed sections in the front face of the rear cover extend radially from the accessory drive and starter shaft supporting boss and conduct the oil to the accessory drive bushings. A tube extending from the top of the annulus conducts oil to a pressure gage connection.

ACCESSORY DRIVES MAGNETO AND GUN SYNCHRONIZER DRIVES—The two upper drilled ribbed sections supply oil to each magneto drive shaft bushing and from there to each magneto drive shaft and then to each gun synchronizer drive shaft (if gun synchronizer drives and their supports are installed).

FUEL PUMP-DUAL ACCESSORY DRIVES — The lower right drilled passage provides oil to the fuel pump-dual accessory drive shaft bushing and from there to the fuel pump drive shaft inner and outer supporting bushings. A passage is drilled angularly through the supercharger rear housing cover at the fuel pump-dual accessory drive shaft bushing. Oil under pressure travels through this passage to lubricate the dual accessory drive gear box and accessories requiring engine oil for lubrication.

OIL PUMP DRIVE—Oil from the lower left drilled pressure passage enters the inside of the oil pump drive shaft bushing.

A drilled ribbed section intersects the oil pressure passage to supply oil to the generator drive shaft bushing.

The clutch control valve receives operation and lubrication oil from a drilled passage intersecting the branch passage from the oil pump drive shaft supporting boss to the generator drive shaft boss.

The supercharger rear housing cover is drilled at the base of a recess behind each accessory drive shaft bushing to drain the surplus oil into the supercharger rear housing.

ACCESSORY DRIVE AND STARTER SHAFT The major quantity of oil arriving at the accessory drive and starter shaft bushing annulus enters the hollow accessory drive and starter shaft through holes in its rear journal. In passing through the accessory drive and starter shaft, some of the oil is forced through a hole drilled in the shaft near its front end to lubricate the impeller shaft supporting bushings. From the accessory drive and starter shaft the oil enters a recess in the rear crank cheek.

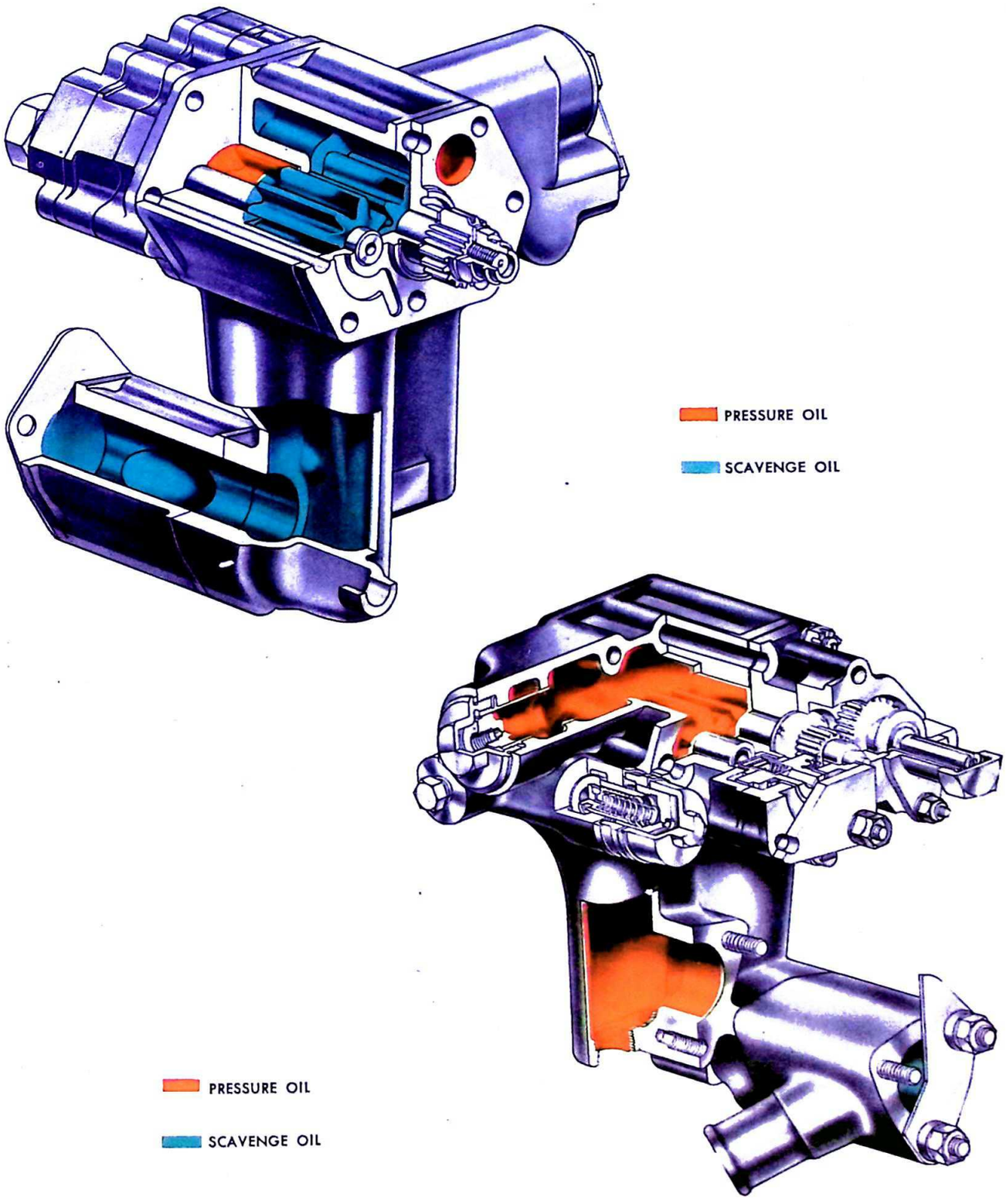


Figure 17—Cutaway View of Oil Pump

CRANKSHAFT REAR CRANK CHEEK A hole drilled through the rear crank cheek conducts the oil into the center of the hollow crankpin, to be discussed under CRANKSHAFT CENTER SECTION. Oil is conducted through drilled passages in the rear crank cheek from the recess at the rear of the crank cheek to an annulus surrounding the floating damper pin bushings.

CRANKSHAFT CENTER SECTION Three tubes (two tubes in earlier engines) extending into the hollow crankpin conduct oil to the outer surface of the crankpin to lubricate the master rod bearing and knuckle pin bushings. The oil enters an annulus in the knuckle pin lock plate and is conducted through the lock plate arms to lubricate the knuckle pins and articulated rod bushings. An oil jet screwed into the front end of the crankpin supplies lubrication for the cylinder walls and piston pins through spray. The motion of the crankshaft and connecting rods assures effective splash lubrication for the roller bearings.

CRANKSHAFT FRONT EXTENSION The oil is led from the crankpin through a drilled passage in the front crank cheek to the hollow crankshaft front extension. The crankshaft front extension acts as an oil reservoir for the cam and reduction gear assembly lubrication. This reservoir is also one source of supply for the propeller governor.

CAM MECHANISM—Oil is conducted from the crankshaft through a hole to the reduction driving gear spacer and to the cam supporting boss on the crankcase front main section. Through indexing passages, oil is led from the boss to the cam drive support. Drilled passages in the support conduct oil to the cam drive gear and pinion bushing; to the sump pump drive gear bushing; and to the cam bearing.

PROPELLER SHAFT—From the reservoir in the crankshaft front extension, oil also takes these paths: Through a forward hole drilled in the wall of the crankshaft to an annulus in the propeller shaft rear supporting bushing. From this annulus oil is conducted through a hole in the wall of the propeller shaft to supply oil to the propeller governor and to the rear of the outside diameter of the bushing to lubricate the planetary reduction gears. Oil from this annulus lubricates the inside diameter of the propeller shaft rear supporting bushing and is led out of the front end of this bushing to travel along the annular space between the crankshaft and the propeller shaft internal sleeve. This oil joins the oil escaping out the front end of the crankshaft to lubricate the propeller shaft front supporting bushing.

Through the crankshaft front exension to hydro-oil fittings in the propeller shaft to supply hydro-low pressure oil for a hydromatic propeller. (If an electric or test propeller is used this passage is blocked off). Some of the oil escaping out the front end of the crankshaft is distributed by a flat on the surface of the crankshaft to lubricate the propeller shaft front supporting bushing.

16:9 REDUCTION GEARING—Lubrication of the .5625 (16:9 ratio) reduction gearing is as follows: Oil is supplied to longitudinal grooves on the outside diameter of the propeller shaft rear supporting bushing through drilled holes in the bushing and flows back into a circumferential groove in the bushing. From this groove oil is conducted through drilled passages in the propeller shaft pinion supporting flange to an annulus formed between the rim of the flange and the attached pinion carrier ring. From this annulus the oil is fed to the floating pinion bushings. Surplus oil escaping from the ends of the bushing provides oil for the planetary reduction gear teeth.

3:2 REDUCTION GEARING—Lubrication of the .666 (3:2 ratio) reduction gearing is as follows: The oil is supplied to the longitudinal grooves on the propeller shaft rear supporting bushing in a similar manner as described above; however, from the circumferential groove in this bushing, the oil is led directly to a passage drilled in each of the six spider arms on the propeller shaft to lubricate each spider arm bushing.

HYDRO-LOW AND HYDRO-HIGH OIL Oil passing through the hole in the wall of the propeller shaft passes through drilled holes at the rear of the oil seal sleeve. Oil then passes through a drilled passage in the stationary reduction gear support and through an indexing passage in the crankcase front section to an annulus around the governor intermediate drive shaft gear bushing. Some of the oil enters through two holes in this bushing to lubricate the governor intermediate drive shaft. The majority of oil from the annulus joins oil from the external hydro-oil system to provide low-pressure oil to the governor and to lubricate the valve tappets.

High-pressure oil returns from the propeller governor through indexing passages similar to those by which the low-pressure oil was conducted from the propeller shaft to the governor. The returning high-pressure oil is led to the hydro-oil fittings through the annular space between the propeller shaft and an internal sleeve.

EXTERNAL HYDRO-OIL TUBE The external hydro-oil tube is mounted on a boss at the left of the starter pad where it receives oil from the annulus in the accessory drive and starter shaft

bushing. Oil is conducted through the external hydro-oil tube to a tapped hole adjacent to the intake valve tappet boss of cylinder No. 7 in the crankcase front section. At this point the oil is introduced into the valve tappet oil supply annulus.

Oil is led from this annulus to the upper valve tappet guides to lubricate the valve mechanism; and through a drilled passage in the crankcase front section that intersects the annulus surrounding the governor intermediate drive gear shaft bushing.

This intersecting passage allows hydro-line oil to join crankshaft oil in supplying low-pressure oil to the propeller governor; and also allows crankshaft oil to join hydro-line oil in lubricating the valve mechanisms.

VALVE MECHANISM Drilled passages leading from the valve tappet annulus supply oil to the eight valve tappet assemblies above the horizontal center line of the engine. Oil is metered into a hollow valve tappet every time a drilled hole in the reciprocating tappet coincides with a hole in the valve tappet guide. Surplus oil lubricates the inside diameter of the guide, tappet roller, hub, pin, and cam lobes. The oil is forced into the valve clearance adjusting screw through indexing holes and passages in the valve tappet and push rod. The screw is drilled with three radial passages through one of which oil is delivered to a groove in the rocker and then forced through a drilled passage to the rocker arm bearing. Oil lubricates the bearing and escapes out its ends to supply lubrication to the rocker roller and valve stem.

Excess oil drains down the inside of the push rod housing and is returned to the engine crankcase through an angularly drilled passage in the valve tappet guide which aligns with a spotfaced corner of the tappet roller slot in the crankcase. The following rocker assemblies are lubricated by pressure oil feed: cylinders No. 1, 2, and 9, both intake and exhaust; cylinder No. 3, exhaust; cylinder No. 8, intake.

The rocker assemblies below the horizontal engine center line are lubricated by oil seeping through the clearance between each valve tappet and its guide, after which it runs down the inside of the push rod housing and the hollow push rod to fill the rocker box. The desired quantity of gravity fed oil for this purpose is obtained by the valve tappet diametrical clearances in their guides.

TWO-SPEED ROLLER CLUTCH The oil lubricating the roller clutch drive is taken from the oil passage leading to the generator drive shaft bushing. This oil is conducted through a small drilled passage in the rear cover to an annulus around the supercharger control valve.

From this point, some of the oil flows through a drilled passage to the annulus around the rear end of the impeller intermediate drive shaft rear bushing for its lubrication and then through the hollow shaft. Oil flows through drilled holes in the impeller intermediate drive shaft to lubricate the impeller intermediate drive gear bushing and journal. The remaining oil continues through the hollow shaft and out the front end to lubricate the front bushing and journal of the impeller drive gear. From the front end of the shaft, oil also flows rearward through slots in the impeller drive gear then through the front cage bushing through drilled holes in the pinion front cage to lubricate the pinions and bushings.

DUAL ACCESSORY DRIVE Engine oil under pressure enters the left side of the dual accessory drive housing through a drilled passage which indexes with a supply passage drilled in the supercharger rear housing cover.

HOUSING—In the housing, oil is conducted from the drilled supply passage to an annulus around the main drive gear front bushing in the upper left corner, and from there to the annulus around the sintered bushing in the upper right corner of the housing. A drilled passage from this annulus leads oil to the center bronze bushing, and from there to the bushing in the lower left corner of the housing.

COVER—Oil is conducted to the dual accessory drive housing cover from the annulus in the upper right corner of the housing where a drilled passage mates with a drilled passage in the cover. Oil from this passage in the cover lubricates the bushing in the upper right corner of the cover and is then conducted to the bushing in the upper left corner of the cover. Oil from the lower left bushing in the housing is conducted through drilled passages and mating holes to the cover and lubricates the lower left bushing in the cover. Drilled passages here lubricate the center bushing in the cover.

SCAVENGE SYSTEM The majority of oil in the lubrication system drains into the sump and is scavenged by the sump pump. Oil from the supercharger rear housing is drawn into the scavenge gears in the oil pump on the rear cover. See figure 18.

Oil from the crankcase front section drains through a hole in the bottom of that section into the sump at its front end.

Some of the oil in the crankcase main section may drain

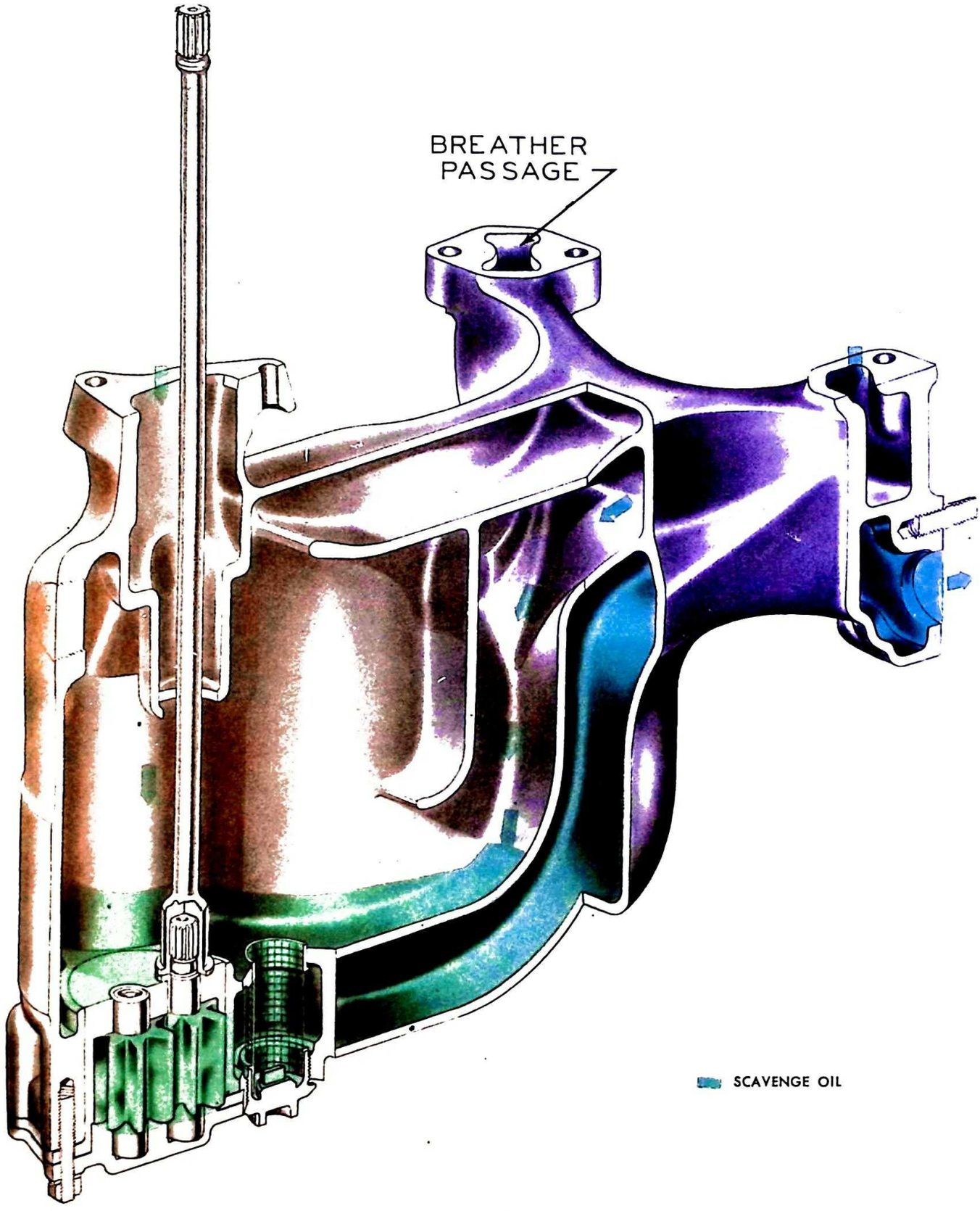


Figure 18—Cutaway View of Oil Sump

through holes in the front diaphragm into the crankcase front section, where it joins front section oil draining into the front end of the sump. For the most part, however, crankcase main section oil drains through holes in the rear diaphragm to the bottom of the supercharger front housing and from there into the left arm of the sump.

All of the oil in the supercharger rear housing is scavenged through a cored suction passage in that housing by the scavenge gears in the oil pump on the rear cover. All of this oil passes through a wire screen strainer that is inserted into the cored suction passage from the lower left side of the supercharger rear housing. The scavenge gears deliver the oil into a "Y" connection in the adapter at the outlet side of the oil pump.

Oil draining into the sump is removed from the sump by means of a sump pump which pumps the oil back through an external oil scavenge line to the "Y" connection in the adapter at the outlet side of the oil pump. Oil from the sump here meets the oil from the scavenge gears in the oil pump to return to the external oil tank.

BREATHER

On engines in this series that breathe through the crankcase, vapors enter the sump through the oil drain passages and leave the sump through a hole in the mounting flange of the right arm of the sump, which indexes with a hole in the bottom of the supercharger front housing. Here vapors enter a cored passage around the rim of the supercharger front housing diaphragm and exit to the atmosphere through a breather flange on the top center line of the housing. In some of the models in this series this flange is replaced by an air-maze oil separator. A spring-loaded relief valve in the supercharger front housing diaphragm opens if abnormal pressure builds up in the crankcase, thus giving the vapors a short route to the atmosphere.

Crankcase pressures between the supercharger rear housing and the main section are equalized by means of two drilled holes at the top of the supercharger rear housing.

Engines that breathe through the crankshaft are provided with a breather tube assembly in the crankshaft and a breather tube rear support in the front crank cheek. On these engines the vent on the top of the supercharger front housing is plugged.

For crankcase breathing, the breather tube assembly is omitted and the breather tube rear support in the front crank cheek is replaced by a substituting plug. The propeller shaft fittings at the front end of the crankshaft depend upon the type of propeller employed and upon the type of engine breathing.

SECTION III

OPERATION

This section contains information pertinent to the ground operation of the Cyclone 9HC engine regardless of the airplane in which it may be installed. Specific airplane operating instructions are furnished by the aircraft manufacturer. The safety of all persons involved, as well as the performance and service life of the engines, depend largely upon strict adherence to these recommendations.

Should difficulty be encountered in normal operation, consult section V on "Engine Troubles and Their Remedies".

PRE-OILING Filling the engine oil passages under pressure from an external source while rotating the crankshaft is termed pre-oiling. This procedure insures satisfactory lubrication at an initial start when the oil system cannot supply adequate pressure. A portable hand pump fitted to a suitable container, or, where pre-oiling is practiced on a large scale, a portable rig fitted with an electrically driven pump, container, and heating element may be used for forcing oil into the oil passages of an engine. Attach a length of hose and a fitting suitable to connect the rig to the location from which the ¼-inch pipe plug has been removed. If an electric heating unit is used, it must be of a type that does not allow direct contact between the heating element and the oil, since this impairs the lubricating quality of an oil.

Pre-oiling should be effected prior to starting a new engine for the first time in an airplane; when starting a newly overhauled engine on a test stand or in an airplane; at the initial start of an engine which has been treated for storage; or whenever an engine has been standing for any appreciable length of time. After an oil change it is necessary only to eliminate air from the oil inlet lines and oil pumps as described below in steps 1, 3, and 4. To pre-oil the engine completely, proceed as follows:

1. Fill the engine oil tank to a safe operating level.

2. Remove the ¼-inch pipe plug from the left side of the oil pump body.

3. With the ignition switch in the "OFF" position and the mixture control in "CUT-OFF", turn the crankshaft (by hand or starter) until sufficient oil is expelled through the ¼-inch pipe tapped hole to indicate that no air remains in the oil pump.

4. Force all air out of the pre-oiling pump and tubing. Connect the pre-oiling pump to the ¼-inch pipe hole.

5. Pump two to three gallons of hot oil at 38°C (100°F) into the engine. Use clean engine oil of the brand with which the engine is normally operated.

While it is preferred to use heated oil, where equipment that embodies heating elements is not available, it is permissable to dilute the oil with fuel in the following proportions:

Oil Temperature	Gasoline	Oil
16°C (60°F) or above	10%	90%
—1° to 16°C (30° to 60°F)	20%	80%
—18° to —1°C (0° to 30°F)	30%	70%

Such dilution will reduce the oil to the same viscosity as the recommended oil at 38°C (100°F).

6. Remove the pre-oiling pump and install the pipe plug.

The engine should be operated immediately after pre-oiling. If the engine has been slushed with preservative compound, run the engine until normal operating cylinder head temperatures have been reached, then drain the oil system. Refill with oil conforming to Aeronautical Material Specification No. 3070. If the engine has not been slushed, the oil need not be drained.

PRIMING The priming system provides an immediate charge of fuel to the engine induction system during starting operations. On restarting an engine that has been shut down, the action of the carburetor is unstable and fuel metering is not accurately controllable until there is a considerable amount of air flow through the carburetor. The priming charge reaches the induction system without going through the process of carburetion.

The degree of priming necessary for successful starting will depend upon the temperature of the engine, temperature of the incoming air, the force of the spray, and the volatility of the fuel. The requirements will range from no priming when the weather and the engine are warm to maximum priming during extremely cold weather when the engine is cold.

The most satisfactory procedure for each particular installation depends to a great extent upon the type of starter used, the kind of carburetion employed, and the primer equipment installed on the engine.

In order to prime an engine, the proper fuel pressure (see step 6 of STARTING) must first be obtained with the hand wobble or electric auxiliary fuel pump. In some installations these fuel pumps are set for a pressure lower than that stated in the starting procedure. This is acceptable although the desired pressures afford a better priming spray.

Priming is effected by a primer fuel valve, which may be manually or electrically (solenoid type) operated, or by a hand primer pump.

When a primer fuel valve is used, the quantity of fuel delivered for priming will be dependent upon the pressure in the main fuel system to which it is connected, and the duration of the priming operation. A successful prime is highly contingent on experience.

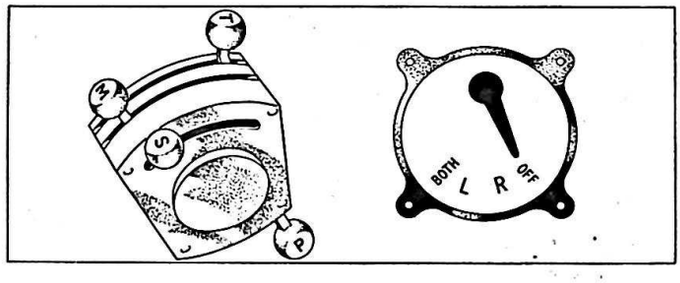
With a hand primer pump the fuel is drawn in slowly until the pump is completely filled, then it is discharged quickly. A swift release gives maximum atomizing at the discharge nozzles with resultant maximum vaporization. The length, frequency, and number of pump strokes necessary for a specific engine installation can only be determined by trial under varying conditions.

The general procedure which follows is recommended for priming all engines under normal temperature and operating conditions, regardless of the type of primer used or the number of priming jets in the system.

Operate the primer and press the starter engaging switch simultaneously, except in the case of a cartridge starter. Continue priming steadily until the engine commences to fire, smooth engine operation is then procured by working the primer intermittently. At low atmospheric temperatures, when using a solenoid type primer valve, smooth initial running may be obtained by holding the primer switch on until the engine has been running for several seconds on the priming charge alone. When the carburetor starts to function, it will be necessary to decrease priming until the engine runs evenly on the main fuel supply.

Priming should not be administered before starter engagement, with one exception as noted above. If the engine is equipped with a cartridge type starter, the priming procedure should be altered for starting in cold weather. It may be impossible for this type of starter to rotate the crankshaft for more than one-half a revolution when weather is extremely cold. In this instance only, it is permissible to prime the engine moderately before the crankshaft begins rotating.

Excessive priming should be avoided as this may load the cylinders with liquid gasoline and in so doing not only make starting difficult but tend to wash the oil from the cylinder walls. A fresh application of oil should be sprayed lightly into the cylinders on an engine that is going to stand a day or more after several unsuccessful attempts at starting have been made. The amount of oil sprayed into one cylinder should not exceed one-quarter ounce and extra precaution should be taken at next start when checking for liquid lock. Underpriming and overpriming may prevent combustion from taking place, or may prevent the engine from continuing to run after having started. Excessive priming will be evident by black smoke or greyish mist emanating from the exhaust system or by liquid fuel running out of the supercharger drain valve. Should overpriming exist, first ensure that the ignition switch is in the "OFF" position and that the mixture control is in "CUT-OFF", then open the throttle wide and turn the engine over several revolutions in the normal direction of rotation. This operation is performed to assist in ridding the engine of excess fuel.



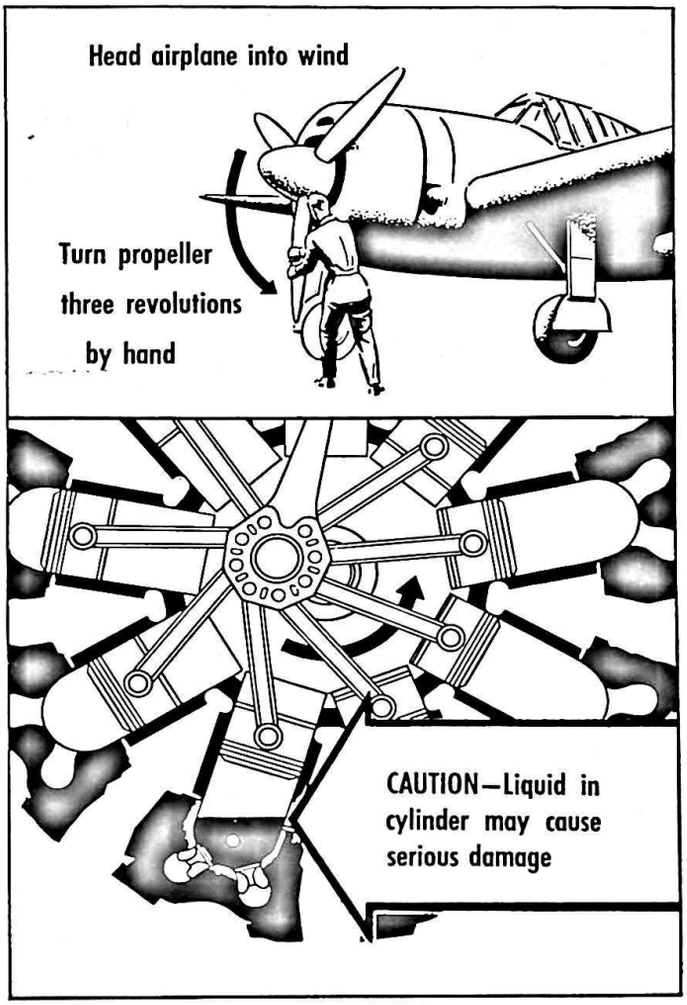
If the cause of hard starting is underpriming, it will be indicated by backfiring. Should underpriming be suspected, administer further priming carefully.

STARTING Before starting any engine, ensure that no loose tools or equipment are lying on or about the engine or airplane. All fastenings should be properly secured. Chocks should be placed in front of the airplane wheels or the parking brakes should be locked in the "ON" position. The quantity of fuel and oil in all the tanks should be checked and all controls should be examined for full travel. It is important that the following starting procedure be performed in the sequence given:

1. Head the airplane into the wind.
2. Set the following controls in the positions indicated:
   Cowl flaps ..... "OPEN"
   Oil cooler shutters ..... "CLOSED"
   Ignition switch ..... "OFF"
   Propeller governor ..... "INCREASE RPM" (low pitch)
   Mixture ..... "CUT-OFF"
   Carburetor air heat ..... "COLD"
   Supercharger ..... "LOW"
   Intercooler shutters ..... "OPEN"

On engines incorporating turbosuperchargers, turbosupercharger boost should be off.

3. With the throttle wide open, turn the propeller in the normal direction of engine rotation at least two complete revolutions. Never turn the propeller opposite to engine rotation when performing this operation, as such action may force liquid into an intake pipe, from where it is apt to be drawn back into the cylinder when the engine is started.



4. If there is any apparent high compression, remove the spark plugs from the lower cylinders and drain out all liquid. The presence of any quantity of liquid in the combustion chamber of a cylinder is likely to cause serious damage.

5. Adjust the following controls as noted:
Fuel supply valve.....“ON”
Throttle.....Set for a maximum of 1200 rpm

6. Obtain a fuel pressure of 17 ± 2 pounds per square inch (1.20 ± .14 kilograms per square centimeter) with the auxiliary fuel pump.

7. Engage the starter and operate the primer according to previous instructions.

8. As soon as the propeller starts to turn, perform the following rapidly:

(a) Turn the ignition switch to “BOTH”.

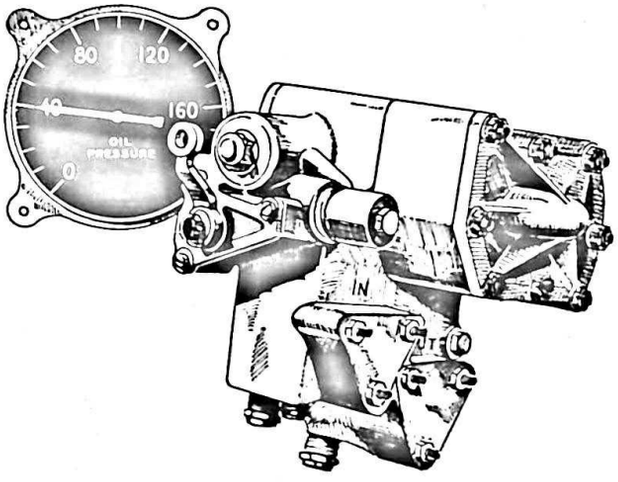
(b) Operate the booster ignition.

If the characteristics of the engine installation make it difficult to perform the starting procedure as stated, it will be satisfactory to switch the ignition on immediately before engaging the starter and to perform item (b) after the starter is engaged, provided the engine is equipped with a booster coil. When an induction vibrator is used, the procedure outlined in steps 7 and 8 must be followed to avoid damage to the engine and to the starter.

Should the engine fail to start within 30 seconds after starter engagement, let the starter cool. Repeat the starting procedure.

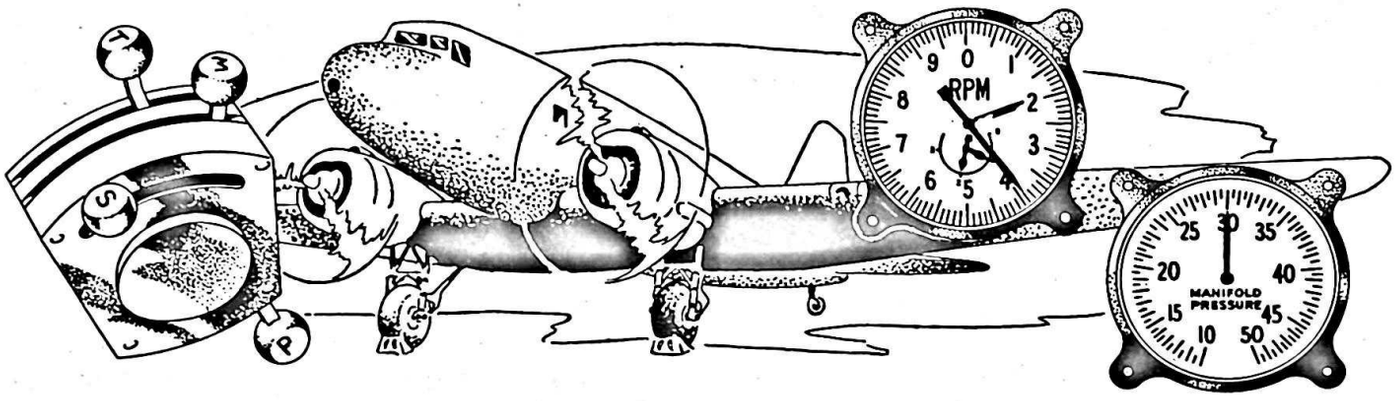
9. When the engine is firing evenly, move the mixture control to the “AUTO-RICH” position. Continue to operate the auxiliary fuel pump until the engine driven fuel pump is supplying sufficient pressure.

10. Stop the engine if the oil pressure gage does not register within five seconds or reach 40 pounds per square inch (2.81 kilograms per square centimeter) within ten seconds after starting.



WARM-UP A thorough warm-up is recommended before making any performance tests and before taxiing to take-off. The following procedure should be adopted for all airplanes:

1. Head the airplane into the wind.



2. Keep the mixture control in the "AUTO-RICH" position.

3. Leave the supercharger control in the "LOW" position.

4. Set the shut-off cock for the manifold absolute pressure gage drain in the "OPEN" position for a few seconds to clear the line of liquids and vapors. This should be done at idling speeds only.

5. Leave the cowl flaps in the "OPEN" position. Closed cowl flaps do not shorten the warm-up period and may result in cylinder fin cracking, burning of the ignition insulation, or other difficulties.

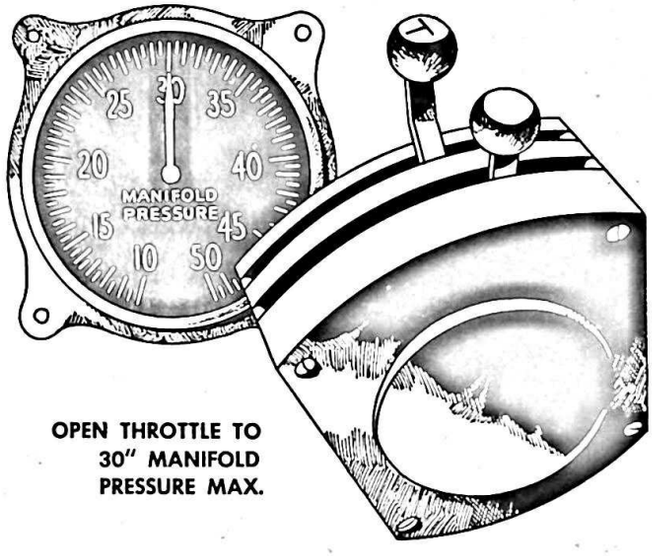
6. Run the engine at approximately 1200 rpm with the propeller governor control set at the "INCREASE RPM" (low pitch) position.

7. Keep the oil cooler shutters in the "CLOSED" position until the oil reaches a satisfactory operating temperature, then open the shutters as required.

8. Continue warm-up until a 10°C (18°F) rise in oil temperature is noted; this is an indication of proper flow. Fluctuation in the oil pressure is generally due to air trapped in the oil line or cold oil. When this condition exists, the oil pressure may be stabilized by extending the warm-up period.

GROUND CHECKS All checks made on the ground should be conducted with the propeller governor control in the full "INCREASE RPM" (low pitch) position and with the mixture control in the "AUTO-RICH" position. When there is a two-speed supercharger engine installation, the supercharger control should be in "LOW" position.

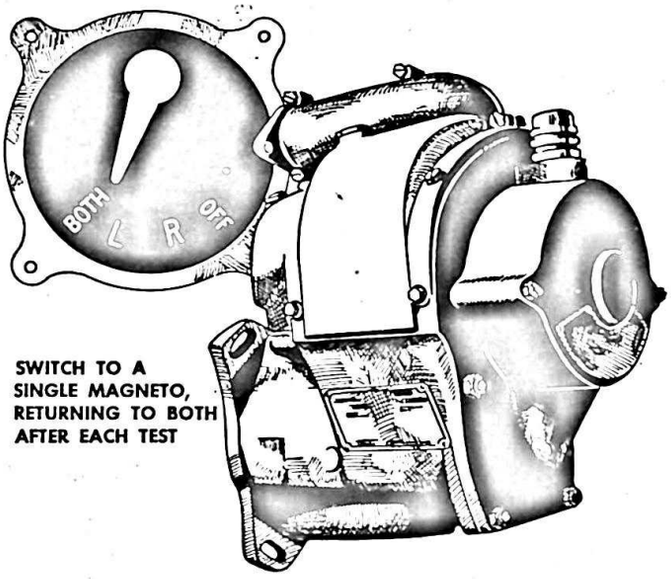
OIL PRESSURE—Open the throttle to not more than 30 inches Hg manifold absolute pressure. Should the oil pressure drop or fluctuate as engine speed is increased, the warm-up period has been insufficient. If the oil pressure is not within the limits at the desired temperature, adjust the oil pressure relief valve.



OPEN THROTTLE TO 30" MANIFOLD PRESSURE MAX.

IGNITION SYSTEM—An ignition system check is conducted with the throttle adjusted to give 28 to 30 inches Hg manifold absolute pressure and an rpm not in excess of 2400. In the event that this throttle opening gives a speed exceeding 2400 rpm, insure that the condition is a normal one. Provided such is the case, the speed should be checked under 2400 rpm in the method applicable to the type of propeller used. If the engine is equipped with an electric propeller, set the propeller in the manual control at a value slightly under 2400 rpm. When the particular propeller does not have an automatic release, note that it must be removed from manual control at the conclusion of the check. If the engine is equipped with a hydromatic propeller, set the control so that it is governed at a suitable speed just under 2400 rpm. With this type of propeller the check must be performed quickly, otherwise the automatic governing action will return the rpm to 2400 before any drop in rpm could be observed.

To check the performance of the ignition system, note the rpm as the engine operates with the ignition switch in the "BOTH" position. Then, without changing the throttle setting, operate the engine with the switch in the "LEFT" position and observe the rpm. The ignition switch should be returned to the "BOTH" position after each check to permit the engine speed to stabilize. Repeat the above procedure for the "RIGHT" position. Atmospheric conditions will influence the readings obtained, however, a drop of 65 rpm or less is considered normal providing no engine roughness is encountered.



SWITCH TO A SINGLE MAGNETO, RETURNING TO BOTH AFTER EACH TEST

At the start of the day's flying, it is necessary to check the "OFF" position of the ignition switch to assure proper connection of the ground wires. This check should be made with the engine turning over approximately 700 rpm. The switch should be turned to "OFF" momentarily to note whether or not the engine stops firing, and immediately returned to the "BOTH" position.

PROPELLER GOVERNOR CONTROL—A propeller governor control check is made as quickly as possible with the engine running at approximately 1500 rpm. Place the propeller governor control in full "DECREASE RPM" (high pitch) position and check for reduction in rpm and full recovery when the control is returned to the "INCREASE RPM" (low pitch) position. Do not move the throttle during this procedure.

TWO-SPEED SUPERCHARGER CLUTCH CHECK—Set the engine speed with the throttle at 1700 rpm. Move the supercharger control lever to the "HIGH" position and lock. Open the throttle to obtain not over 30 inches Hg manifold absolute pressure. When the engine speed stabilizes, observe the manifold absolute pressure and immediately shift to "LOW" without moving the throttle. A sudden decrease in manifold absolute pressure indicates that the two-speed mechanism is operating properly.

GROUND ADJUSTMENTS

CARBURETOR IDLE SPEED AND MIXTURE—The engine should be warmed thoroughly before adjusting the carburetor idle speed and mixture. There are three phases of engine operation which may be seriously affected if improper idle adjustments are made, (1) taxiing, (2) acceleration, (3) landing. There are two acceptable procedures for making carburetor idle adjustments. The first method is as follows:

1. Make an ignition system check in the usual manner.

2. With the mixture control in "AUTO-RICH" position, adjust the throttle stop so that the engine idles at 400 rpm or at the lowest possible smooth idling speed.

3. Adjust the idle mixture control to give maximum speed at this throttle setting.

4. Readjust the throttle stop to idle the engine at 400 rpm or at the original idling speed.

5. Readjust the idle mixture control to give maximum speed.

6. Reset the throttle stop to the minimum idle speed desired.

The second procedure is the so-called "cut-off" method.

1. Make an ignition system check in the usual manner.

2. Idle the engine at approximately 500 rpm with the mixture control in "AUTO-RICH" position. If the rpm increases appreciably after a change in the idle mixture adjustment during the succeeding steps, readjust the closed throttle stop to restore the desired rpm.

3. When the speed has stabilized, move the cockpit manual mixture control quickly and smoothly into the "CUT-OFF" position and observe the tachometer for any change in rpm during the leaning process. Return the control to "AUTO-RICH" position before the rpm can drop to a point where the engine cuts out. An increase of more than 10 rpm while "leaning out" indicates an excessively rich idle adjustment. An immediate decrease in rpm indicates the idle adjustment is too lean.

4. If steps 2 and 3 indicate that the idle adjustment is too rich or too lean, turn the idle adjustment one or two notches in the direction required for correction, and check each new position by repeating steps 2 and 3. Make additional readjustments as necessary until a check with steps

2 and 3 results in a momentary "pick-up" of approximately 5 rpm (never more than 10 rpm). After the idle mixture has been satisfactorily adjusted to give the 5 to 10 rpm increase, the closed throttle stop should be set to give the desired idling rpm.

Periodically during either adjustment procedure the engine should be run up for a few seconds to approximately 60 percent of rated power on "AUTO-LEAN" mixture. This clears out the excess fuel and oil which tend to collect in the induction and exhaust systems resulting in spark plug fouling and making adjustments erratic and difficult.

OIL PRESSURE ADJUSTMENT—The normal operating oil pressure limits, as read from the oil pressure gage, are 65 to 75 pounds per square inch (4.57 to 5.30 kilograms per square centimeter). These limits are to be maintained throughout the cruising and high power range, however, at idle speeds, the pressure may fall off slightly. Oil pressure should be checked by operating the engine within the stated limits at an oil inlet temperature of 70° to 85°C (158° to 185°F). If the check indicates a need for further adjustment, reduce the engine speed to minimum cruise rpm. Readjust the oil pressure relief valve by turning the slotted adjusting screw in a clockwise direction to increase, and counterclockwise to decrease the relief valve spring tension and engine oil pressure. Since at this low rpm the valve is bottomed, it will be necessary to run the engine up again to recheck the adjusted oil pressure. It is advisable to set the pressure near the high limits to allow for reduced oil pressure at high oil temperature.

PROPELLER FEATHERING AND UNFEATHERING In feathering a propeller the blade pitch is increased sufficiently to eliminate windmilling. It is primarily an emergency procedure in the event of an engine failure. Practice feathering and unfeathering can be conducted if caution is observed. During practice tests, keep to a minimum the length of time the propeller is left in the feathered position in order to avoid liquid lock in the lower cylinders and excessive cooling.

FEATHERING PROCEDURE—1. Close the throttle completely. This eliminates a tendency to backfire.

2. Place the mixture control in the "CUT-OFF" position.

3. Set the propeller governor control in full "DECREASE RPM" (high pitch) position. Low engine speeds also reduce the tendency to backfire.

4. Perform the following operations simultaneously or as rapidly as possible in sequence:

(a) Press the feathering switch but do not hold down as it will automatically release when the feathering operation is complete.

(b) Shut off the fuel supply to the engine being feathered by means of the selector valve or the fuel shut-off valve.

5. The ignition switch is placed in the "OFF" position after the propeller has stopped turning. It should be remembered that in order to avoid dangerous afterfiring during feathering, the engine should stop because of lack of fuel and not because the ignition has been turned off.

6. Place the generator switch in the "OFF" position.

UNFEATHERING PROCEDURE—The mixture control should still be in the "CUT-OFF" position and the throttle closed.

1. Set the propeller governor control in the full "DECREASE RPM" (high pitch) position.

2. Turn the ignition switch to "BOTH".

3. Open the throttle to give a maximum engine speed of 1200 rpm.

4. Press the feathering switch and hold down.

5. Turn on the fuel supply to the engine as soon as the propeller has turned approximately three revolutions. This is done to clear the lower cylinders of liquid.

6. When the engine speed reaches 800 rpm, release the feathering switch.

7. Place the mixture control in "AUTO-RICH" position.

8. Set the generator switch in the "ON" position.

9. Operate the engine at as near 1000 rpm as possible until satisfactory cylinder head and oil temperatures are obtained. Be sure to obtain the proper fuel and oil pressure.

10. Adjust the propeller governor control to the desired rpm after the engine has been warmed up.

11. Adjust the throttle for the desired manifold absolute pressure.

STOPPING If the air temperature warrants diluting the oil, adopt the procedure given in this section under "Oil Dilution" before stopping the engine. To stop the engine, proceed as follows:

1. Keep the cowl flaps in the "OPEN" position when stopping and after the engine has been shut down.

2. Set the propeller governor control in the "INCREASE RPM" (low pitch) position.

3. Leave the supercharger control in "LOW" position.

4. If the engine has been warmed up by taxiing, idle the engine until the cylinder head temperatures have dropped to a maximum of 150°C (300°F) or to a value consistent with existing atmospheric temperature.

5. Immediately before shutting down the engine, open the throttle to give 1000 to 1200 rpm for a period of at

least 30 seconds. This provides maximum scavenging of the crankcase oil.

6. Place the mixture control in the "CUT-OFF" position. Do not move the control out of this position after stopping the engine. If the fuel pressure is greater than 5 pounds per square inch (.35 kilogram per square centimeter) and the mixture control is out of this position, whether the engine is running or not, the fuel will flow and may collect in the lower cylinders.

7. When the propeller stops turning, place the ignition switch in the "OFF" position.

8. Close all fuel shut-off valves.

9. If the engine is to remain idle for an extended period of time, cover the carburetor airscoop, the exhaust ports, and all similar passages.

COLD WEATHER PROCEDURES FOR GROUND OPERATION Normal starting procedures as recommended in this section should be used at all times regardless of the type of starting aids employed. A normal start can usually be made above a temperature of —15°C (5°F) without resorting to additional equipment. Difficulty in starting may be experienced, however, at any temperature below 0°C (32°F) depending upon the relative humidity of the atmosphere. High humidity conditions reduce the rate of fuel vaporization and greatly accentuate spark plug icing. Consequently, operations conducted in coastal areas and particularly with sea planes or flying boats are subject to considerable difficulties. Conversely, operation carried out in desert areas at very low relative humidity will experience less trouble with lower temperatures. Should trouble arise in starting in cold weather, an appropriate measure may be selected from those discussed below to provide satisfactory starting.

APPLICATION OF EXTERNAL HEAT—The application of sufficient external heat to an engine permits starting at any temperature without the use of dilution, special fuels, or other means. Heating is recommended, therefore, as generally the most satisfactory method of overcoming all cold weather starting difficulties.

To meet this requirement, equipment should be available that is capable of delivering heat continuously to the front and rear of the cylinders, to the rear sections, and to the oil tank, battery, and other accessories. A quilted kapok or other suitable cover should be placed over the dome of the propeller and back over and around the cowling. This cover should be so installed that air circulation is held to a minimum, and should incorporate provisions for sufficient heater pipe inlets. Heat should particularly be applied to the engine accessory section and to the carburetor to aid in maintaining vaporization of fuel during and after starting.

Heating should continue until the cylinder head temperature reaches 20°C (68°F). This allows for the cooling which takes place during the preparation prior to starting. The engine should be started before it cools to 0°C (32°F) at which point spark plug icing will occur.

USE OF AUXILIARY PRIMING SYSTEMS—In the case of water based aircraft, the use of external heat may be difficult since equipment of this type cannot be handled readily over water. As an alternative, resort to special priming fuels.

Normal aviation fuels do not vaporize in sufficient quantity below —18°C (0°F) to provide satisfactory and consistent starting. If a high humidity is present, vaporization may be insufficient at —29°C (—20°F). To overcome this condition it is possible to introduce a more volatile fuel into the priming system. Numerous paraffin base, pure hydrocarbon fuels of this type are available some of which vaporize sufficiently at temperatures as low as —56°C (—70°F).

In starting engines at air temperatures below zero, winter automotive gasoline having a Reid vapor pressure of 15 pounds per square inch (1.05 kilograms per square centimeter) will permit successful starting to as low as approximately —29°C (—20°F). Ether as a priming fuel, although not perferred due to its being toxic and to its low antiknock value, has, when used, permitted successful starting to —29°C (—20°F). Pentane, which is a highly volatile fuel, has been used successfully at —34°C (—30°F).

The use of various priming systems, nozzles, and pressures has very little effect on the relative amount of fuel vaporization for starting. Large increases in priming pressure provide little or no increase in the proportion of fuel vaporization. Any beneficial results realized by increasing the priming pressures are probably due to the improvement of a nozzle spray characteristic. However, nozzle spray efficiency may be reduced by this condition of higher pressures, particularly if fuel is injected in such quantity that it strikes the cold walls of the induction system before vaporizing. This will reduce the proportion of fuel vaporization.

It has been found that the standard priming nozzle is satisfactory for use in cold weather starting when either standard fuel or special high volatile fuels are used. The nozzle should be inspected when improper flow and spray characteristics are suspected, by using gasoline or water at 6 pounds per square inch (.42 kilogram per square centimeter) pressure. At this condition a satisfactory cone

spray should be obtained with no "dribbling" and the rate of flow should be 40 to 55 pounds per minute.

It is desirable that all cylinders receive priming fuel to insure a successful start on the first attempt. If some cylinders do not fire from lack of priming fuel, it is possible that the spark plugs of these cylinders will be subject to icing. The two-point priming system, with the discharge nozzles located in the carburetor adapter, is the most satisfactory from this consideration. This system also reduces the possibility of liquid lock by not introducing fuel at such a location that lack of vaporization or subsequent condensation would tend to fill the lower intake pipes.

A portable priming unit can be constructed with a small tank of one or two gallons capacity equipped with an electric pump. The pump outlet can be teed into the regular two-point priming system by a quick sealing coupling. Power for the electric pump can be obtained by installation of a cannon plug connection and a primer solenoid line. Thus no additional control or circuits are required on the airplane.

The tank may be filled with the chosen priming fuel or the fuel may be mixed with standard aviation gasoline for less severe temperatures. It is suggested that special fuel be mixed with an equal amount of the standard fuel for temperatures down to —18°C (0°F). Below this the special fuel may be used with no mixing and with minimum possibilities of vapor lock.

The pressure output of the auxiliary priming pump should be high enough to ensure satisfactory nozzle spray. Normally, standard fuel pressure required for the particular installation will be sufficient.

OIL DILUTION—When the auxiliary priming systems are used for cold weather starting, or when the oil tank cannot be satisfactorily heated, it will be necessary to dilute the oil with gasoline prior to stopping the engine so that subsequent starting will be satisfactory.

Dilution is recommended when air temperatures are —34°C (—30°F) or lower. The values given in the table following should be used only in the absence of authenticated information generally supplied by the aircraft manufacturer and placarded in the cockpit. Operate the engine at 1200 rpm maximum maintaining oil temperature below 50°C (122°F) and oil pressure within recommended limits. Hold the oil dilution valve open for the time specified at each temperature condition.

The conditions are:

0° to —12°C (32° to —10°F)	3 minutes
—12° to —29°C (—10° to —20°F)	6 minutes
—29° to —46°C (—20° to —51°F)	10 minutes

Add one minute dilution for each addition 5°C (9°F) below —46°C (—51°F).

During the last two minutes of the oil dilution operation, dilute the turbosupercharger regulator and hydromatic propeller system, provided the airplane is so equipped.

For airplanes having turbosupercharger regulators operated by engine oil and individual turbosupercharger regulator controls in the cockpit, move the regulator over the complete range from low to high ratio and return at the rate of eight seconds per cycle (at least 14 complete movements from low to high ratio and return).

For airplanes having hydromatic full feathering propellers using engine oil as the actuating fluid, the propeller feathering switch will be depressed until a drop of 400 rpm is observed, at which time the switch will be pulled out and the rpm allowed to return to normal. This operation will be repeated three times.

For airplanes having hydromatic propellers which are not full feathering, the propeller governor control will be advanced until a drop of 400 rpm is observed, after which the propeller governor control will be returned to its original position, to allow the rpm to return to normal. Repeat this operation three times.

Return the dilution switch to the "OFF" position and shut down.

The oil, when diluted, will usually permit the starter to turn the engine at a fairly high rate of speed without the necessity of pre-heating the oil. After the engine has started, the gasoline will gradually evaporate as the oil temperature rises.

If, after starting, a highly viscous oil is indicated by an oil pressure that is too high or by an oil pressure that fluctuates or falls off when engine rpm is increased, the dilution valve may be operated to correct this condition. However, this procedure is not considered good practice but may be resorted to, provided the oil dilution valve is operated intermittently and is not held open for continuous periods. If, during this process, the oil pressure drop should be too low, stop the engine, drain the system, and replenish the oil supply with warm undiluted oil before attempting to start again.

OIL DRAINAGE—If forced to land when cold weather starting facilities are not available, keep the engine warm by occasional run-ups or else drain the oil system immediately after shutting down and then refill with warm oil just prior to starting. If the oil is allowed to congeal within the engine, extreme difficulty will be experienced before circulation can again be obtained.

SPARK PLUG ICING—Icing inside the combustion chamber occurs when the temperature drops below 0°C (32°F) and any moisture condensed from the air freezes. This condition effectively "shorts out" the spark plugs, preventing starting. The higher the atmospheric relative humidity the more serious this condition becomes and it is aggravated by the fact that the lead salts deposited in the combustion chamber from the combustion of fuel are hygroscopic in nature thus tending to collect moisture readily.

Spark plug icing can easily be caused by "false starting", in which the engine fires a few times and then cuts out. The water product of combustion then freezes in the combustion chamber. Therefore, it is essential that the first starting attempt be successful.

Installation of heated spark plugs in a cold engine or taking a warm plane from a hangar to cold air also tends to produce plug icing, unless the engine is started immediately. Of more success is the installation of spark plugs which have been thoroughly chilled and dried. This does not give rise to an atmospheric moisture condition which condenses and freezes after the engine spark plugs cool.

HEATING THE BATTERY—It has been proven that batteries which are kept warm at all times will more nearly approach their capacity output than batteries that are cold. Batteries are rated at an air temperature of 27°C (80°F), and the performance of even a new fully charged battery decreases as the temperature decreases. This is not a straight line relationship as indicated by the table below which is calculated on a 300 ampere discharge.

Temperature	Percentage of Output in Relation to Capacity at 27°C (80°F)
5°C (40°F)	93
—18°C (0°F)	76
—29°C (—20°F)	55
—34°C (—30°F)	30
—37°C (—34°F)	5

Batteries when being charged should be in an air temperature of 5° to 27°C (40° to 80°F) since this procedure is also affected by atmospheric conditions. Most battery manufacturers specify a maximum temperature of not more than 60°C (140°F).

When bringing a battery from an aircraft or from storage for recharging, sudden changes in temperature should be avoided to minimize the possibility of splitting battery cases. A battery that is cold should be heated to at least 5°C (40°F) before charging to ensure maximum battery life and minimum charging time. This is applicable to a battery being charged on a bench, in a hangar, or by the generator on the engine while in flight.

ACCESSORY FREEZING—Trouble has been experienced below —18°C (0°F) with freezing of engine mounted accessories resulting in sheared accessory shafts when the engine is started. The vacuum pump in particular has been subject to this condition since the moisture compressed from the air during operation freezes after the engine has been shut down. Other accessories experience a similar trouble due to lack of lubrication at engine starting. Since this lubrication is provided by engine oil through metering passages, normal oil dilution does not appreciably relieve this condition.

WARM-UP—It may be necessary after the engine has started to use carburetor air heat to prevent subsequent engine cutting out. This will occur when the intake air is at a low enough temperature to reduce fuel vaporization below the amount needed to maintain engine operation.

The entire engine warm-up should be conducted according to instructions under normal operation. In the case of a diluted engine, the warm-up should continue until all fuel has been evaporated from the oil. If, however, the oil pressure remains constant, the airplane may be flown.

SECTION IV

SERVICE INSPECTION

In order to obtain maximum reliability and service from engines, a regular schedule of inspections and maintenance should be observed. Serious failures may arise from minor causes which a few minutes of inspection could have revealed in time for preventive measures.

The fact that installations vary must be recognized in the preparation of any inspection recommendations. Installation characteristics may prevent some of the inspections at the times specified. In these cases, it is recommended that a more suitable period be set. However, whenever any deviation from the inspection periods established by the recommendations in this section is considered, the operator is urged to determine a specific time interval for the inspection of that part.

The work outlined is a normal function of the operating organizations. It consists of the periodic inspection, cleaning, servicing, lubricating, adjusting, and such maintenance work as is associated with the routine inspection system.

Inasmuch as the following recommendations apply mainly to the engine, it should be emphasized that existing instructions of the various aircraft, propeller, and accessory manufacturers pertaining to the correct maintenance, inspection, and repair of their products be rigidly followed.

The inspection procedure consists of the following: Installation Inspection, conducted immediately following initial ground run-up; Daily Inspection; 25 Hour Inspection after Installation; and Periodic 100 Hour Inspection.

SERVICE INSPECTION CHART

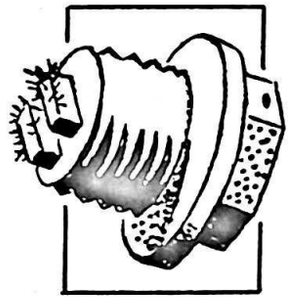
	Installation and 25 Hour after Installation Inspection	Daily Inspection	100 Hour Inspection
Air Deflectors	X	X	X
Carburetor Air Filter	X	X	X
Carburetor Attachment	X		X
Compression			X
Controls	X	X	X
Cylinder Fins	X	X	X
Engine Exterior			X
Exhaust System	X	X	X
Fuel Leakage	X	X	X
Fuel Strainer	X	X	X
Fuel Tank Sumps	X	X	X
Ignition Harness	X	X	X
Intake Pipes			X
Magnetic Sump Plug	X		X
Nuts and Cap Screws	X	X	X
Oil Change			X
Oil Cooler Cores	X	X	X
Oil Strainers	X		X
Oil Leakage	X	X	X
Spark Plugs			X
Valve Clearances	At the 25 Hour after Installation Inspection *only*.		

INSTALLATION AND 25 HOUR AFTER INSTALLATION INSPECTION

In addition to the items listed in Daily Inspection, check the following:

CARBURETOR ATTACHMENT—See that the carburetor and adapter are securely fastened.

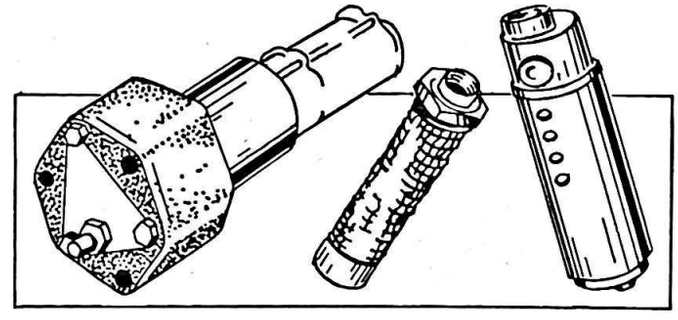
FUEL STRAINER—Remove and clean the main fuel strainer. Reinstall using new gaskets.



MAGNETIC SUMP PLUG—Remove and inspect for metal particles the magnetic plug, located at the bottom of the sump. Analyze any metal particles which may be found. Any evidence of this kind should be investigated thoroughly to determine whether or not the engine should be disassembled. Reinstall the plug using a new gasket.

NUTS AND CAP SCREWS—Inspect *all* nuts and cap screws to insure that they are tight and properly locked.

OIL STRAINERS—Remove the oil screen strainer located under the magnetic drain plug in the sump. Remove the oil screen strainer located at the left side of the supercharger rear housing and remove the oil strainer located at the bottom of the supercharger rear housing. Clean any sludge from the units, and reinstall using new gaskets. Analyze metal particles as previously noted.



VALVE CLEARANCES—Remove the rocker box covers and check the valve clearances. Reset any clearances which are not within the limits specified in section II. Ensure that the valve clearance adjusting screw lock screw is tight. The engine should be cold when setting or checking these clearances. Check for broken valve springs every time a rocker box cover is removed. Valve clearances should be checked at the end of the first 25 hours after installation and thereafter as operating experience indicates. Ensure adequate lubrication prior to installation of cover.

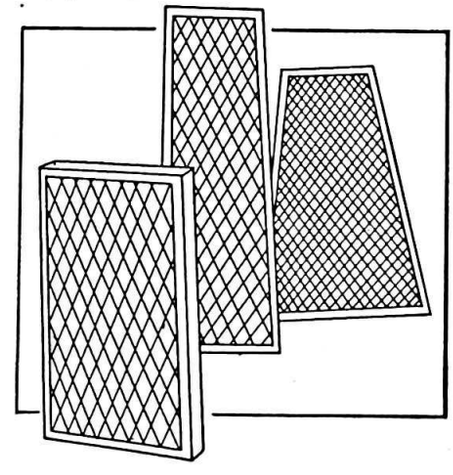
DAILY INSPECTION

AIR DEFLECTORS—See that the air deflectors are tight and that clearance exists between the deflectors and the cylinder fins. Check the deflectors for cracks and dents.

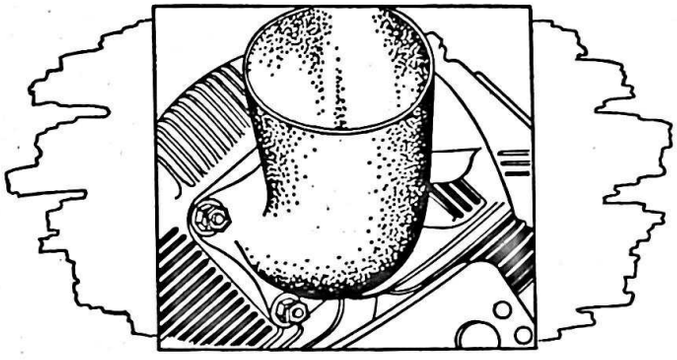
CARBURETOR AIR FILTERS—Inspect the carburetor air filters visually, and, if necessary, service according to existing instructions.

CONTROLS—Check all controls for proper functioning before flight: throttle, mixture, cowl flaps, supercharger, propeller governor, carburetor airheat, etc. Lubricate all joints and bearings requiring lubrication.

CYLINDER FINS—Inspect the cylinder fins to make sure they are not clogged with dirt. Check for any cracked fins. The extent and location of the crack will determine whether the cylinder must be replaced or the crack may be removed by profiling. An engine with a cracked cylinder fin should not be operated until the condition has been corrected.



EXHAUST SYSTEM—Check the exhaust pipe or exhaust manifold for cracks or misalignment.



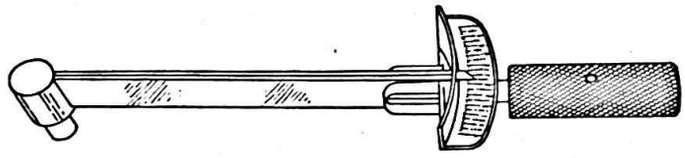
FUEL LEAKAGE—See that all fuel connections are tight. Replace any parts that cannot be tightened properly. Inspect the engine carefully for fuel leakage, frequently indicated by dye stain from the fuel. The location of a leak may not always be where the stain is found. Replace or repair any parts which are causing fuel to leak. If leakage is observed at the intake pipe packing nut, the packing must be replaced before the nut is tightened.

FUEL TANK SUMPS—Clean the fuel tank sediment bulb or sumps.

FUEL STRAINER—Remove and inspect main fuel strainer.

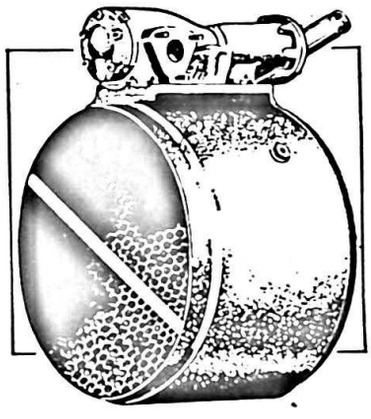
IGNITION HARNESS—See that the spark plug terminals are secured. The terminal nuts should be snug but care must be taken not to damage the nuts by overtightening. Visually inspect all ignition leads for cracks and chafing.

NUTS AND CAP SCREWS—Inspect all accessible nuts and cap screws daily to insure that they are tight and properly locked. Experience has indicated that a great many cases of bolt and stud failures have been caused by excessive tightening of nuts. For this reason, it is recommended that nuts should not be tightened further if they are already secure, and the correct tightening torque as listed in the Table of Limits should be used. A number of torque indicating wrenches is available, some of which have a scale in inch-pounds, and others have an arbitrary



scale which can easily be converted to inch-pounds or centimeter-kiiograms. Each operation base should have one or more of this type wrench on hand.

OIL COOLER CORES—Inspect the cores of the oil cooler to make sure that they are not plugged or coated with dirt. Ensure that any foreign material which would obstruct air flow is removed.



OIL LEAKAGE—Check for oil leakage. If any leakage is indicated, locate the source. Indications of leaking oil may be discovered away from the point of origin. Check rocker box covers and all oil connections. See that the connections are tight. When tightening will not correct the leak, repair or replace the necessary parts.

100 HOUR INSPECTION

In addition to the 100 Hour Inspection listed below, Daily Inspection items must be included.

CARBURETOR ATTACHMENT—See that the carburetor is securely fastened.

COMPRESSION—Check the compression of all cylinders. Whenever the spark plugs are removed from the cylinders it is advisable to make a complete compression check. A set of figures obtained by a compression check should be approximately the same if the cylinders and piston assemblies are in good condition. If, however, the compression of one or more cylinders appears to be considerably lower than the rest and cannot be easily corrected, it would be well to remove and replace the entire cylinder assembly.

ENGINE EXTERIOR—Clean and inspect the exterior of the engine thoroughly.

EXHAUST SYSTEM—Check the exhaust system for tightness. If loose exhaust flange attaching nuts are found,

care must be taken to tighten them to the proper torque to ensure that no distortion of the part takes place. Exhaust leakage at this location caused by flange distortion or insecure fastening may result in the burning of the exhaust port.

FUEL STRAINERS—Remove and clean the main strainer. Remove and clean the regulator bleed and strainer on the regulator bleed.

INTAKE PIPES—Check the intake pipe packing nuts and cap screws. Do not tighten intake pipe packing nuts at this inspection, since such tightening will break the adhesive seal of the packing to the intake pipe. The seal cannot be formed again by further tightening. If a leak is evident, the packing must be replaced. A leaking intake pipe is a fire hazard and a possible cause of improper fuel-air ratio. It is therefore recommended that the utmost caution be exercised in following these recommendations.

MAGNETIC SUMP PLUG—Remove and inspect for metal particles, the magnetic plug located at the bottom of the oil sump. Analyze metal particles which may be found. Any evidence of this kind should be investigated thoroughly to determine whether or not the engine should be disassembled. Reinstall the plug with new gaskets.

OIL CHANGE—Drain the oil system and refill with the proper grade of oil. Change of oil is determined mainly by the conditions under which an engine is operated. Generally, oil should be changed every 100 hours. Clean all oil strainers when changing oil.

OIL STRAINERS—Remove the oil screen strainer located under the magnetic drain plug in the sump. Remove the oil screen strainer located at the left side of the supercharger rear housing and remove the oil strainer located at the bottom of the supercharger rear housing. Clean any sludge from the units, and reinstall using new gaskets. Analyze metal particles as previously noted.

SPARK PLUGS—Change the plugs. In general it is recommended that plugs be changed at 100 hour intervals; however, because of basic differences in the design of spark plugs, the period at which plug changes are required will vary. Changes should be made in accordance with the individual operator's experience.

SECTION V

ENGINE TROUBLES AND THEIR REMEDIES

The problem of determining the cause for engine troubles is at times rather involved due to the number of sources to which a given symptom may be attributed. Since there may be many exceptions to a system set up for isolating causes of troubles, no attempt has been made to establish a specific routine for trouble shooting. Instead, the procedures to be followed are left to the discretion of the trouble shooter. Generally, however, it is recommended that the obvious possible causes be checked first.

Because the same malfunctioning part may manifest itself in different types of troubles under different operating conditions, the causes are usually mentioned briefly in the chart and the detailed procedure to be followed in isolating or correcting the difficulty is discussed in the section following the charts. Numbers referring to the paragraphs where applicable information is located are included in the chart.

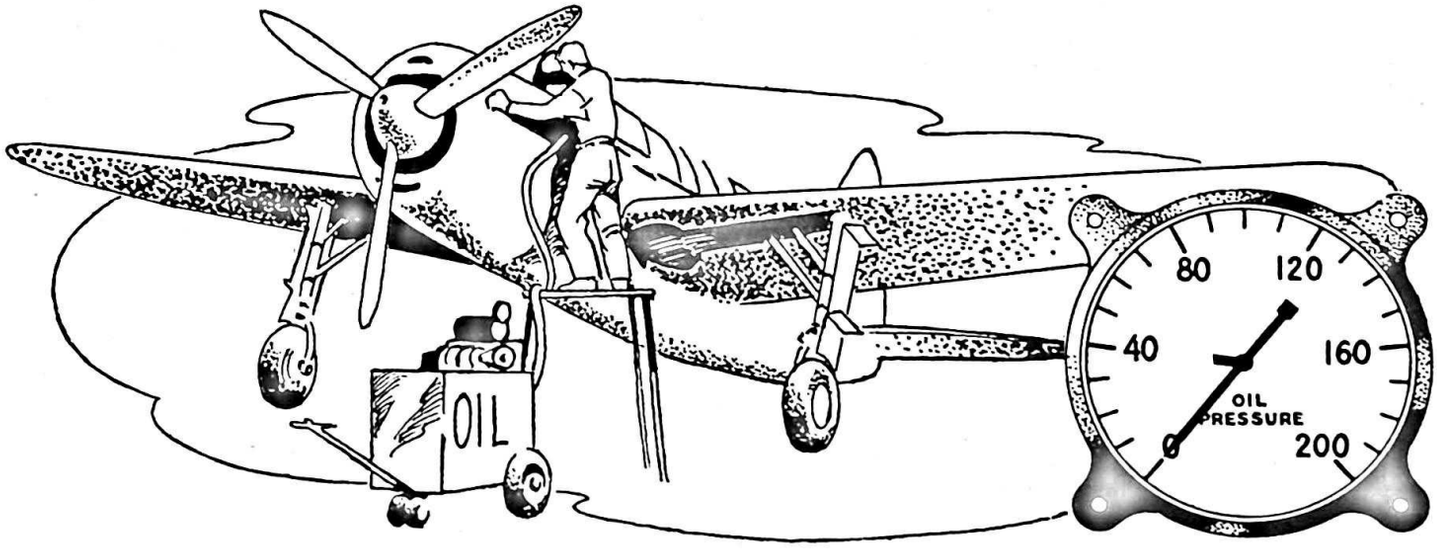
In many cases the remedy is obvious. For example, under the trouble "NO OIL PRESSURE" the cause, "Inadequate Oil Supply," is listed. The apparent remedy is to replenish the supply. When cases similar to this occur, no explanation or remedy is given.

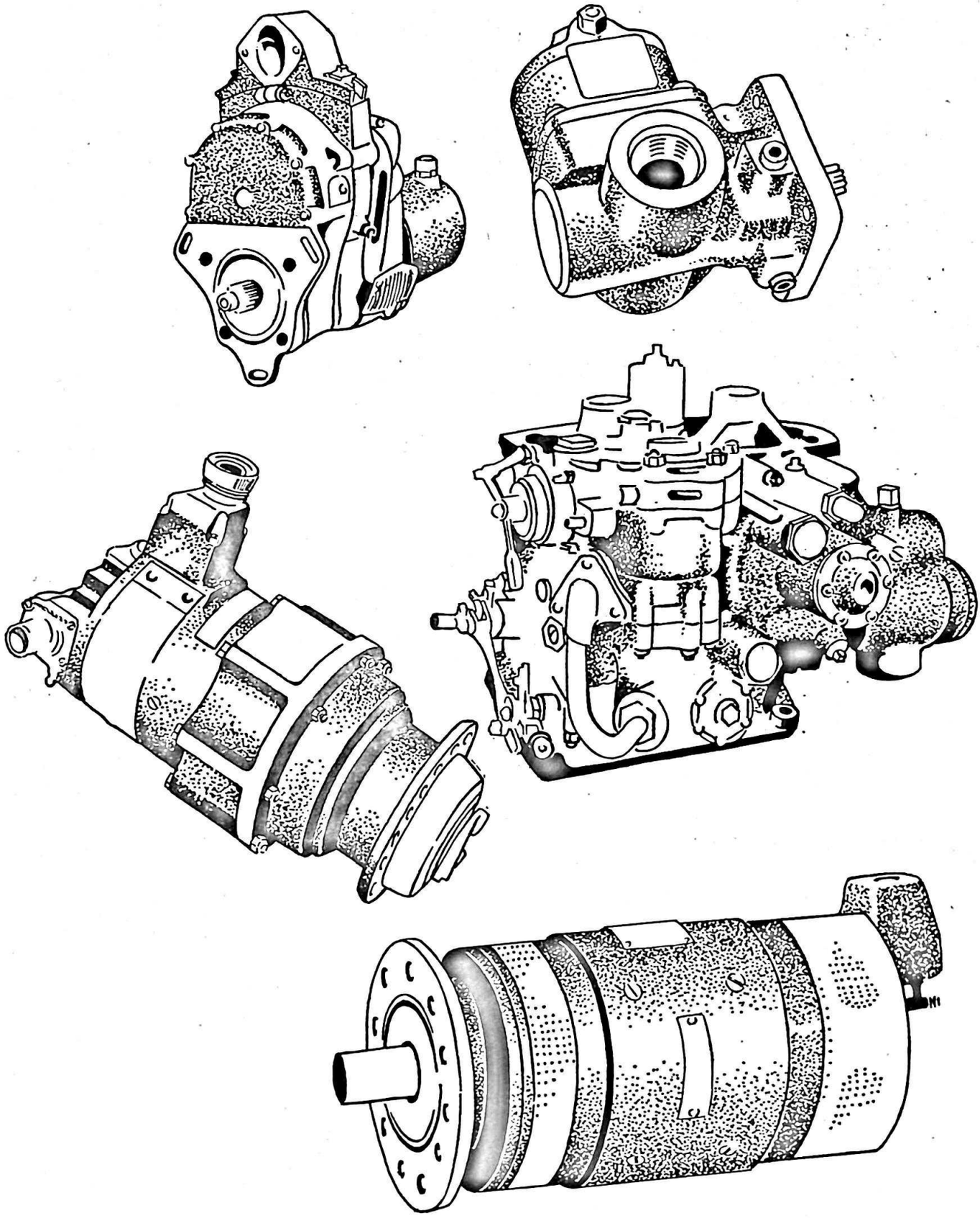
IF THE CAUSE OF AN ENGINE TROUBLE IS NOT OBVIOUS, ALWAYS EXAMINE THE OIL STRAINER AND THE MAGNETIC SUMP PLUG FOR SIGNS OF INTERNAL FAILURE BEFORE PROCEEDING. This procedure is followed in order to determine, before any corrective procedures are taken, whether or not the engine must be removed from the installation for overhaul.

It is well to remember that indications of troubles may be found by studying carefully the cockpit instrument readings, and correct interpretation of such readings may save the trouble shooter considerable time in accomplishing his job. However, malfunctioning instruments may indicate a trouble when none exists. In all cases, check gages, gage lines, or gage controls for accuracy.

Whenever an accessory fails or is the apparent source of trouble, it is best to consult the accessory manufacturer representative or to replace the unit. However, in many cases, when either of these procedures is impractical, the accessory manufacturer's instructions should be referred to. Frequently, accessory publications contain trouble shooting procedures which will assist materially in isolating troubles in the accessory. In all cases the accessory manufacturer's recommendations should be adhered to.

Whenever the spark plugs are removed from the cylinders, a complete compression check is advisable. A set of figures obtained by a compression check should be approximately the same if the cylinders and piston assemblies are in good condition. If, however, the compression of one or more cylinders appears to be considerably lower than the rest and cannot be easily corrected, remove and replace the entire cylinder and piston assembly.





FAILURE OF ENGINE TO START

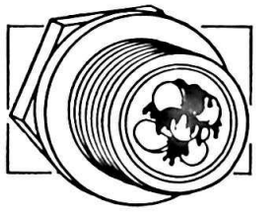
Lack of fuel:
- Low fuel pressure 13
- Improperly operating priming system 14

Lack of spark:
- Faulty booster coil or induction vibrator 11
- Fouled spark plugs 12
- Ice on spark plug electrodes 12
- Weak battery
- Faulty ignition switch
- Faulty magneto ground or disconnect plug at fire wall 6-7

Insufficient valve clearances

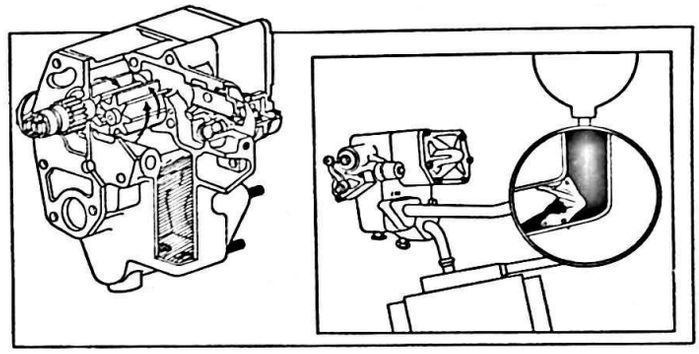
FAILURE OF ENGINE TO CONTINUE RUNNING AFTER STARTING

Underpriming or overpriming 14
Incorrect throttle setting
Lack of fuel
Water in fuel
Vapor in carburetor 33
Malfunctioning carburetor
Obstruction in carburetor air duct
Magneto grounded 6-7
Malfunctioning breaker point assembly 3
Dirty or fouled spark plugs or plugs with improper gap 12
Defective spark plug terminal contactors 8
Faulty ignition switch



NO OIL PRESSURE

Inadequate oil supply
Lack of oil pump priming
Leak in oil line
Air lock in pressure pump
Obstruction in oil-in line
Sheered pump shaft



LOW OIL PRESSURE

High oil temperature (Refer to High Oil Temperature in Trouble column)
Leak in oil line
Inadequate oil supply
Improper setting of pressure relief valve
Air lock in pressure pump
Clogged oil strainers
Oil foaming 39
Sticking pressure relief valve
Improper or defective relief valve spring
Worn bearings or bushings
Loose internal oil passage plug
Scored oil pump pressure gear cavity
Leaking oil dilution valve

HIGH OIL PRESSURE

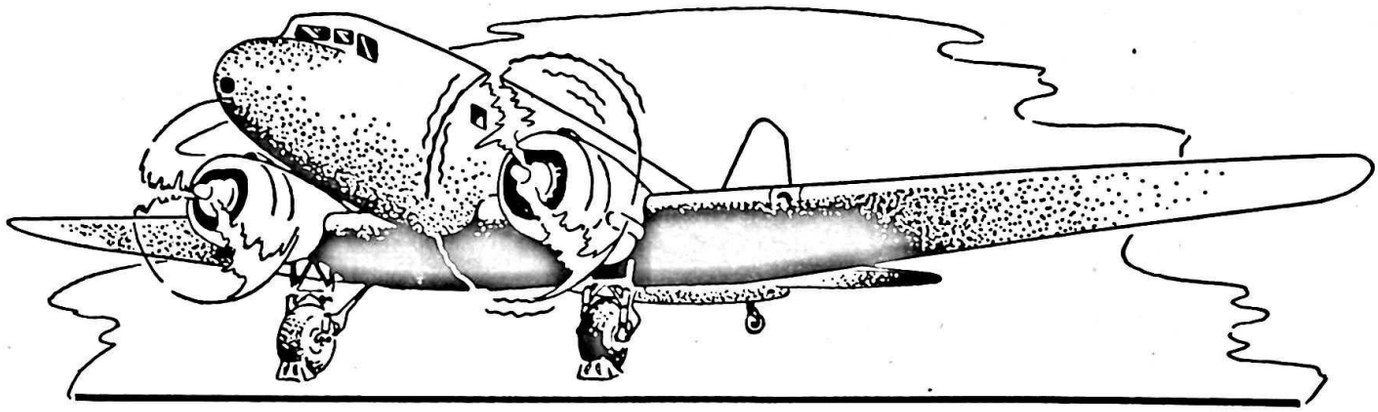
Improper setting of pressure relief valve
Cold oil 36
Sticking pressure relief valve

FAILURE OF ENGINE TO IDLE PROPERLY

Faulty or loose spark plugs 12
Incorrect carburetor idle adjustment 15-16
Leak in induction system 29
Leaking priming system 14
Malfunctioning carburetor
Exhaust port covered
Sticking valves
Improper valve clearances
Condensation in ignition system 3, 8, 12
Carbonized or cracked spark plug terminal contactors 8

ENGINE ROUGHNESS

Ignition trouble 1-12
Improper fuel-air mixture 17-25
Carburetor or adapter ice 30-32
Vapor in fuel line 33
Malfunctioning carburetor



Cowl mounting loose (false indication of engine roughness)
Sticking valve tappets
Worn piston rings
Improper valve clearances
Incorrect valve timing
Burned or sticking valves
Burned pistons
Broken valve springs
Propeller out of balance
Loose propeller
Worn thrust bearing
Loose thrust nut
Bent propeller shaft
Engine mount at fault

BACKFIRING

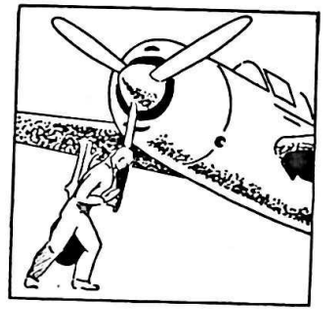
Improper starting and stopping procedures
Mixture too lean 17-25
Excessive fuel 26
Improper fuel 13
Malfunctioning magneto condenser 5
Incorrect magneto timing
Vapor lock in carburetor 33
Carburetor vapor vents clogged 33
Faulty engine valve operation
Exhaust port plugged
Acceleration with propeller in high pitch

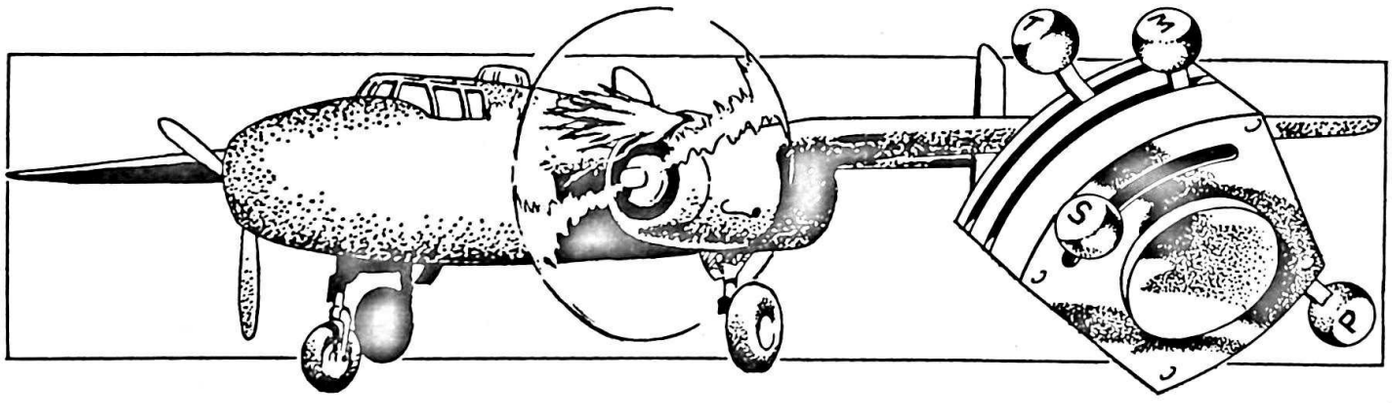
TORCHING (AFTERBURNING)

Inoperative spark plugs 12
Faulty ignition system 1-12
Improper mixture 17-25
Carburetor icing 30-32
Leaking primer 14

FAILURE OF ENGINE TO DEVELOP FULL POWER

Faulty ignition 1-12
Throttle lever out of adjustment
Over-rich carburetor 25
Improper fuel 13
Leaks in induction system 29
Carburetor ice 30-32
Leak in carburetor pre-heat system
Restriction in carburetor airscoop
Improper engine valve action
Low compression





Governor improperly adjusted
Propeller stops incorrectly set
Defective supercharger clutch
Damaged impeller vanes

HIGH OIL TEMPERATURE

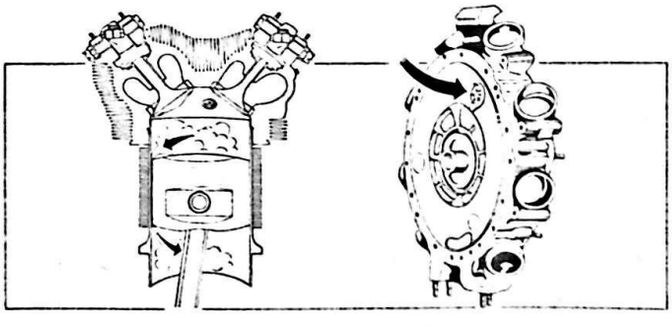
Insufficient oil supply
Low viscosity of oil 35
Oil cooler shutters improperly rigged 36
Oil cooler clogged 36
Contaminated oil supply 35
Congealed oil in the oil cooler 36
Faulty temperature regulator
High oil flow
Bearing failure
Oil foaming 39

OIL ACCUMULATION IN THE CRANKCASE

Engine idling too slowly 15-16
Congealed oil in the oil cooler 36
High oil temperature (Refer to High Oil Temperature in Trouble Column)
Too much oil in tank
Excessive oil dilution
Damaged vacuum pump 6
Damaged oil pump
Leaking check valve
Leaking gaskets in suction side of scavenge system
Air lock in scavenge system

BREATHER OIL LOSS

Cylinder blowby:
  Burned pistons
  Worn or broken piston rings
Oil accumulation in crankcase (Refer to this topic in Trouble Column)
Aircraft aerobatics
Partially clogged breather screen
Breather relief valve stuck closed

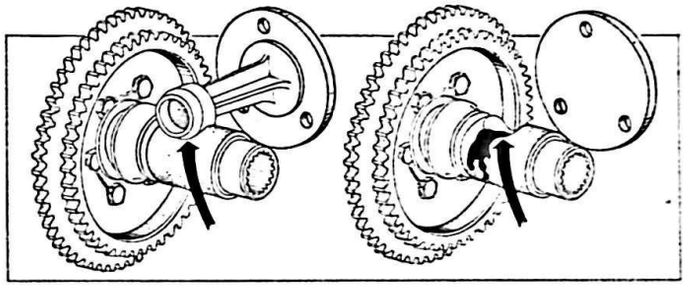


RPM VARIATION

Faulty ignition 1-12
Improper carburetion 13-34
Improper mixture control rigging
Malfunctioning propeller
Malfunctioning governor:
  Dirt in governor
Insufficient oil supply
Malfunctioning turbosupercharger installation
Carburetor ice 30-32

EXCESSIVE OIL CONSUMPTION

Oil leaks, internal and external 43



Breather oil loss (Refer to this topic in Trouble Column) 43
Oil return passage from rocker box plugged
Incorrect installation of piston rings
Bearing failure
Supercharger oil seal vent clogged
Worn or broken piston rings 42
Burned pistons

FAILURE OF HYDRO-CONTROLLED PROPELLER TO FEATHER AND UNFEATHER

Propeller shaft oil transfer rings worn or incorrectly installed
Oil transfer sleeve out-of-round or too loose
Cold oil
Low oil supply
Improper oil seals
Malfunctioning feathering pump
Weak battery
Malfunctioning propeller

METAL OR FOREIGN MATERIAL IN STRAINER, OIL SCREENS, OR SUMP

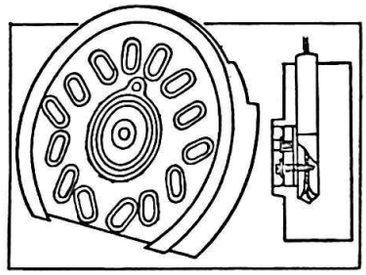
Lack of care in assembling engine
Failed engine parts
Foreign material in oil or oil system
Failed accessory

IGNITION

IGNITION SYSTEM CHECK

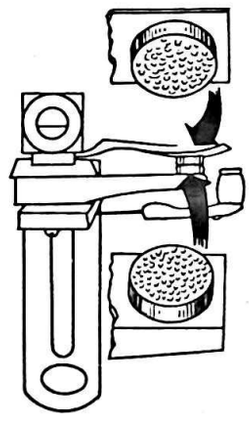
1 Refer to section III for the procedure on the ignition system check.

2 If the engine appears to be rough when operating on one or both magnetos or the loss in rpm is excessive, stop the engine and check for the following: fouled spark plugs; damaged or carbon-tracked spark plug terminal contactors; dirt or oil on magneto breaker points; punctures or moisture in the ignition leads; incorrect timing of either of the magnetos; carbon-tracked distributor rotors; faulty condensers; loose wire connections; improper wire installation. Check to ensure that the piercing screws in the distributor block are making contact with the cable conductors.



BREAKER POINTS

3 If the breaker points are worn, dirty, or badly pitted, remove the breaker point assembly, and clean, repair, or replace if necessary. If the breaker point assembly is removed, it will be necessary to internally time the magneto. Rework of points requires special skill and should only be done by experienced personnel in accordance with the applicable manufacturer's instructions. During normal magneto operation a small amount of burning or pitting of the breaker points may occur which does not necessitate replacement of the breaker assembly. If excessive pitting or burning is evident, check the magneto primary condensers and ensure that no oil or grease is present within the breaker compartments. If it is present, remove with a clean, dry, lintless cloth. The most prevalent source of this trouble is vapors from oil and cleaning fluids. To prevent recurrence ensure that the breather screens are clean and unobstructed.

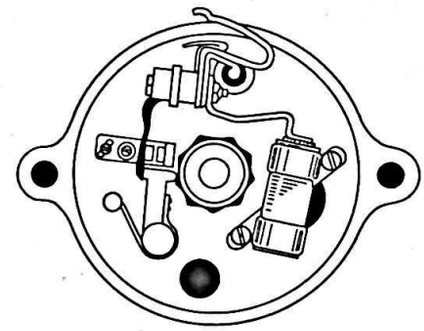


DISTRIBUTOR OR ROTOR

4 If the distributor block or rotor has dirt or carbon deposits, clean the block or rotor. If either is cracked, replace the cracked parts. Refer to the magneto manufacturer's instructions for the correct procedure in cleaning or repairing these parts.

CONDENSERS

5 If a defective primary or secondary condenser is indicated, it is necessary to replace the unit. A defective primary condenser is usually indicated by excessively burned or pitted breaker points. A defective secondary condenser sometimes results in rough engine operation at higher speeds or in weaker magneto output. Refer to the magneto manufacturer's instructions for the replacement of these parts.



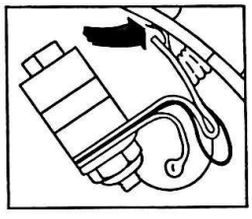
MAGNETO GROUND

6 Should the magneto ground circuits be suspected of shorting out, remove the ground wire from one magneto before starting and then proceed to start and warm up the engine in the prescribed manner. If the engine continues to run satisfactorily after the ignition switch is turned to the "OFF" position, it is an indication that the magneto being checked is operating properly. Stop the engine and reconnect the ground. Repeat the same procedure for checking the other magneto. If both magnetos check out satisfactorily, using this procedure, and the trouble continues to exist after reconnecting the ground wires, the trouble is probably located in the ignition switch, ground wires, cannon plug at fire wall, or induction vibrator circuit. In the case of magnetos incorporating an automatic ground-

ing device, ensure that the magneto does not become shorted to the ground during this test.

7 As a safety precaution, after reinstalling the ground wires, the engine should be operated on both magnetos at a low rpm after which the magneto switch should be turned to the "OFF" position momentarily. The engine should cease to fire. If it does not, the ground wires are not making proper contact.

CAUTION: Always be sure that the proper magneto ground terminal is used and is making proper contact with the magneto ground system.



SPARK PLUG TERMINAL CONTACTORS **8** Remove, clean and dry the terminal contactors. The contactors must be absolutely dry before reinstalling.

CAUTION: Always use acetone or unleaded gasoline in cleaning parts.

If the contactor is cracked, perforated, burned, or has carbon tracks, all of which will cause flashover, replace it. Check the contactor spring for breaks or other damage to the wire. Careful handling of the contactors is very important to prevent breakage or damage during removal from or installation in spark plugs. Care must be taken to prevent moisture from hands from remaining on the contactors during installation, since moisture may cause flashover.

IGNITION HARNESS **9** Check the cables with a standard harness tester. The harness tester manufacturer's instructions should be carefully studied prior to test, since a good harness may be damaged by improper use of some testers.

The method of testing is to disconnect the lead at the spark plug and apply high tension. If high tension is applied to a lead terminating at or adjacent to the distributor fingers, the spark may jump to the distributor finger and the tester will indicate a ground whether that lead is faulty or not.

The following method may be employed for checking harnesses:

It is recommended that a direct current tester be used. A satisfactory method of testing with a direct current tester is as follows:

Connect the "Earth Ground" binding post on the side of the tester to a rod driven into the earth or to any well-grounded object.

Connect the high voltage lead by screwing the threaded connector and "High Voltage" terminal on the front of the ignition tester. (No. 1—red rubber-covered clip.)

Plug the ground lead (No. 2—black plug in connector on one end—black rubber-covered terminal on the other end) into the "Ground" receptacle on the front of the ignition tester panel. Connect the rubber-covered terminal to any convenient metal point on an engine cylinder.

Plug the remote switch lead terminal No. 6 (with push button switch on one end) into plug-in "Remote Switch" terminal on the ignition tester panel.

Make sure all switches are turned "OFF" and that the "High Voltage Control" is set at ZERO, then connect the 110 volt AC extension cord (No. 4) to the plug-in terminal on the front of the ignition tester; connect the other end to the 110 volt AC supply line.

Turn the "Filament" switch "ON." Allow about 10 seconds for the filament to heat up.

Turn the "Plate" switch "ON."

Hold down the switch button of the remote switch. Adjust the "High Voltage Control" until the voltmeter pointer registers 10,000 volts (red mark).

Set the "Resistance Range Switch" on "HIGH" position; any harness lead which gives a meter reading of greater than 50 on the red scale (deducting initial reading caused by leakage of test leads and machine) or which causes the "Breakdown Indicator" to flash should be repaired or replaced.

Releasing the button in the remote control switch automatically turns off the high voltage supply. Do not touch the high voltage terminal lead or the equipment being tested when the remote switch button is depressed.

Owing to danger of flashover within the distributor between electrodes and points of ground, procedures must be followed to have the distance between the points on the distributor rotor and the electrodes of the lead being tested at a maximum. The settings of the cylinders at top center compression stroke using the different magnetos are as follows:

Set engine at top center on the Compression Stroke of Cylinder No.	Test Lead No.
1	2, 4, 5, 7, 9
9	1, 3, 6, 8

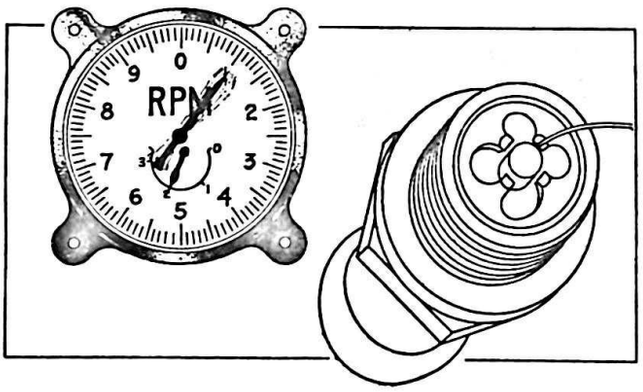
The above procedure will eliminate the necessity for

removing distributor blocks from the magnetos during the harness test. However, if the blocks are removed, it is obvious that the above order of testing is not neccessary.

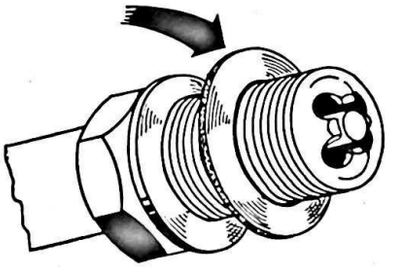
CONNECTIONS **10** Check all electrical connections for tightness. Clean any connections which may be dirty.

BOOSTER COIL AND INDUCTION VIBRATOR **11** If the engine will not start and the booster coil or induction vibrator is suspected of being faulty, check to see that it is properly grounded. If necessary, remove and check the unit according to the applicable manufacturer's instructions.

SPARK PLUGS **12** Poor spark plug operation may cause one or more of the following: engine roughness, failure of engine to start, low power, after burning, pre-ignition, and detonation. During the ignition system check, if the spark plugs are found to be malfunctioning, the plugs should be removed and serviced, or replaced with new or reconditioned plugs. Bomb test the plugs in accordance with the spark plug manufacturer's instructions for indication of proper operation before installation. If the electrode gap is not within limits or if the insulation is cracked or perforated by small burned holes caused by flashover, replace the plugs. If the plugs are dirty or fouled, they should be cleaned or replaced. Spark plug fouling caused by extended idling of the engine may sometimes be cleared by operating at 30 inches Hg manifold pressure for a short interval of time. Operate on both magnetos with the mixture control in "AUTO-RICH." Do not necessarily consider oil-wet spark plugs in the lower cylinders or plugs having a greyish-white lead deposit on the electrodes as fouled. Oil fouled



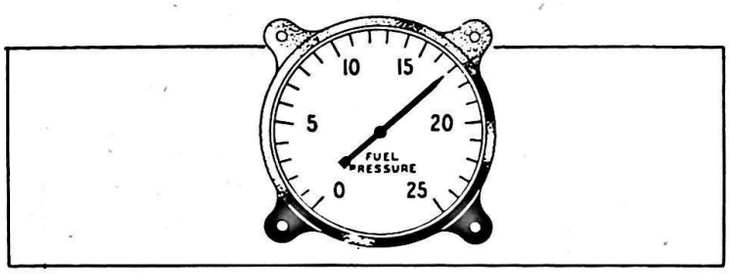
spark plugs are usually covered with a greasy, black, rough carbon deposit. Sometimes in the case of oil-wet plugs, operation will tend to burn off the oil. Wet spark plugs caused by ice forming on the electrodes should be dried thoroughly and replaced. Refer to the spark plug manufacturer's instructions for the proper drying procedure. When replacing spark plugs, always use Lubriplate 130-A compound on the threads, being sure that no compound gets on the electrodes. Mica base lubricants must not be used. Ensure that a spark plug washer of the proper dimensions is inserted between the spark plug and the cylinder head. Always tighten the plugs to the proper torque as indicated in the Table of Limits.



CARBURETION

FUEL AND FUEL PRESSURE

13 Carburetion difficulties may sometimes be traced directly to contaminated fuel. Consequently the condition of the fuel should be checked whenever carburetion troubles are encountered. Always use the fuel which is specified for the engine. Check the fuel pressure.



Fuel pressures vary according to the type of carburetor used. The engine and airplane should be checked for any leaks in the fuel system. Replace or repair any leaking parts. Clean dirty strainers and lines. Check the fuel pressure relief valve for proper operation.

PRIMING

14 The lack of a priming charge may prevent the engine from starting. Check the fuel supply and the fuel pressure. If the pressure is correct, two items should be checked: the priming solenoid and the priming lines and nozzles. Check each priming line and nozzle for restrictions regardless of the type of priming system used. Fuel should flow from the lines with adequate fuel pressure. A leaking priming solenoid will contribute to overpriming. For instructions on eliminating overpriming or underpriming see section III.

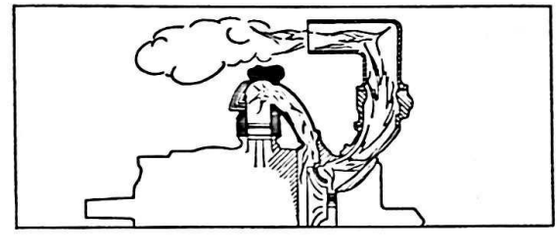
IDLING

15 Poor idling characteristics are usually indicated by torching, backfiring, rough engine operation in the idle range, or poor acceleration. Changes in location of operation, such as moving from a field at sea level to a field at higher altitudes will definitely affect idling characteristics.

16 Idle adjustment involves two factors: idle minimum speed adjustment and idle mixture adjustment. Adjust idle minimum speed by altering the throttle stop adjustment and mixtures by the idle mixture control or "click" adjustment. For instructions on making idling adjustments see section III.

RICH OR LEAN MIXTURE

17 Backfiring through the carburetor scoop or torching in the exhaust system can be corrected in the idle range by adjusting the idle mixture. If the carburetor causes rich, lean, or otherwise erratic operation in ranges above idling, make no adjustments. Certain carburetor parts can be replaced in the field, but the carburetor manufacturer's instructions must be followed. If the carburetor



manufacturer's assistance is not available, remove and replace the carburetor, but only after eliminating other sources of trouble as described in the following:

18 Check and clean the fuel strainer. Check both the induction and the fuel systems for leaks. An induction system leak between the carburetor and cylinders, for example a loose intake pipe, will cause lean mixture flows to the engine resulting in backfiring through the scoop when operating at manifold pressures below atmospheric pressure. When operating at manifold pressures above atmospheric, this condition constitutes a serious fire hazard. It is of utmost importance, therefore, that leaking parts be replaced or tightened. In the case of intake pipe packing nuts, however, no tightening should be done after the packing nut has once been tightened. Tightening these nuts will break the seal already formed and the packing will not adhere a second time. Replace the packing if necessary.

19 Too rich a mixture is usually indicated by black smoke or torching. Check the fuel pressure remembering that fuel pressures vary according to the carburetor. With some carburetors, too frequent acceleration of the engine will cause torching due to overrichness caused by frequent injection of fuel from the accelerating pump.

20 Too lean a mixture may be caused by low fuel pressure, improper rigging of the mixture control, vapor in the fuel system, or leaks in the induction system when operating with manifold pressures below atmospheric. Adjust or replace the fuel pump if necessary. Replace any leaking packing or gaskets. If the trouble persists, replace the carburetor.

21 Backfiring is burning of fuel back through the induction system and carburetor. It may sometimes be observed as a sharp light yellow-orange flame at the carburetor airscoop. If backfiring occurs in the idle range,

adjust the idle mixture as previously suggested. If it occurs above the idling range, inspect the induction system for air leaks that would tend to lean out the mixture since too lean a mixture will cause backfiring. Occasional backfiring or cutting-out may sometimes be caused by air leaks in the fuel system or by the carburetor vapor float not working.

22 With some carburetors, backfiring occurs if the throttle opening is too large for starting. In this case the air taken in is not in proper proportion to the vaporized priming fuel and a lean mixture flow to the engine results. Adjust the throttle opening to 800 to 1000 rpm.

23 Afterburning is the igniting of an unburned charge of fuel and air in the exhaust collector ring. It gives a loud report similar to that accompanying backfiring but is quite different in nature.

24 In some turbosupercharged installations, leaning out can be done inadvertently by improper operation of the throttle and turbosupercharger controls. The carburetor injects the proper amount of fuel into the engine as demanded by the air-flow. The carburetor venturi measures the air-flow while the altitude compensator or automatic mixture control measures the density of the entering air. Ordinarily the altitude compensator or automatic mixture control is not sensitive to pressures above approximately 31 inches carburetor top deck pressure. (In some recent installations, the sensitive range has been increased to 35 inches.) Therefore, power settings should be made first by using the throttle until full throttle is reached and then, if necessary, supplementing the power setting obtained with turbosupercharger boost.

25 A number of operating conditions such as the following list will usually indicate a mechanical trouble in the carburetor. Whenever any of the following operational difficulties are encountered, consult the carburetor manufacturer's representative or replace the carburetor.

1. Engine runs too rich or too lean at cruising power.
2. Engine runs satisfactorily at cruising power but is too rich or too lean at higher power.
3. Engine runs satisfactorily at auto-rich mixtures but is too rich or too lean in the cruising-lean position.
4. Engine does not accelerate properly.
5. Engine does not shut off properly.
6. Engine runs too rich or too lean at cruising power with the manual mixture control in "AUTO-RICH."

EXCESSIVE FUEL **26** Excessive fuel which may cause an engine to backfire may result from a leaking priming system or by the spark plugs failing to fire the charge after it has entered the combustion chamber. In this case the fuel accumulates in the combustion chamber as liquid gasoline and consequently will not burn. However, as the fuel vaporizes a certain amount of the vapor becomes combustible although in a lean form. Consequently when the intake valve opens, the lean, or late-burning mixture will backfire through the induction system. Liquid gasoline lying in the induction system will sometimes ignite causing internal fires. Some of the liquid gasoline in the combustion chamber may be expelled into the exhaust ports and be ignited at that location. This may result in serious torching.

DETONATION **27** Detonation is usually indicated, if indicated at all, by high cylinder head temperatures and rough engine operation. It is frequently accompanied by a sharp whitish-orange flame appearing in the form of intermittent flashes which will be sporadic or explosive in appearance at the exhaust stack. Detonation is a result of fuel characteristics, fuel-air ratios, high cylinder temperatures, and excessively high manifold pressures in relation to rpm and is more pronounced and destructive as temperatures and pressures increase. Therefore, anything such as a climb or maneuver which tends to cut down the cooling air and raise engine temperatures, or the addition of heat to the carburetor air in attempting to avoid icing conditions, or as increases in power causing increases in the pressure within the cylinders, or brake mean effective pressure, should be regarded as actions which increase the tendency of the fuel to detonate. Proper correlation between rpm and manifold pressure is necessary to prevent high brake mean effective pressure that will tend to cause detonation.

28 In cases of suspected detonation, lower the output and control the cylinder head temperatures by opening the cowl flaps.

AIR LEAKAGE IN INDUCTION SYSTEM **29** In turbosupercharger installations with the turbosupercharger off there will be a certain drag through the induction system that will limit maximum manifold pressure obtainable to less than that required. If air leakage occurs, the drag through the sys-

tem will be reduced and higher manifold pressure and power will be available. This same leakage will, however, lower the critical altitude of the engine by reducing the turbosupercharger boost available. See also "Rich or Lean Mixture".

CARBURETOR ICE **30** The formation of ice in the induction system of the engine may be noticed by a gradual falling off of manifold pressure or loss of rpm accompanied by a richening or leaning out of the mixture.

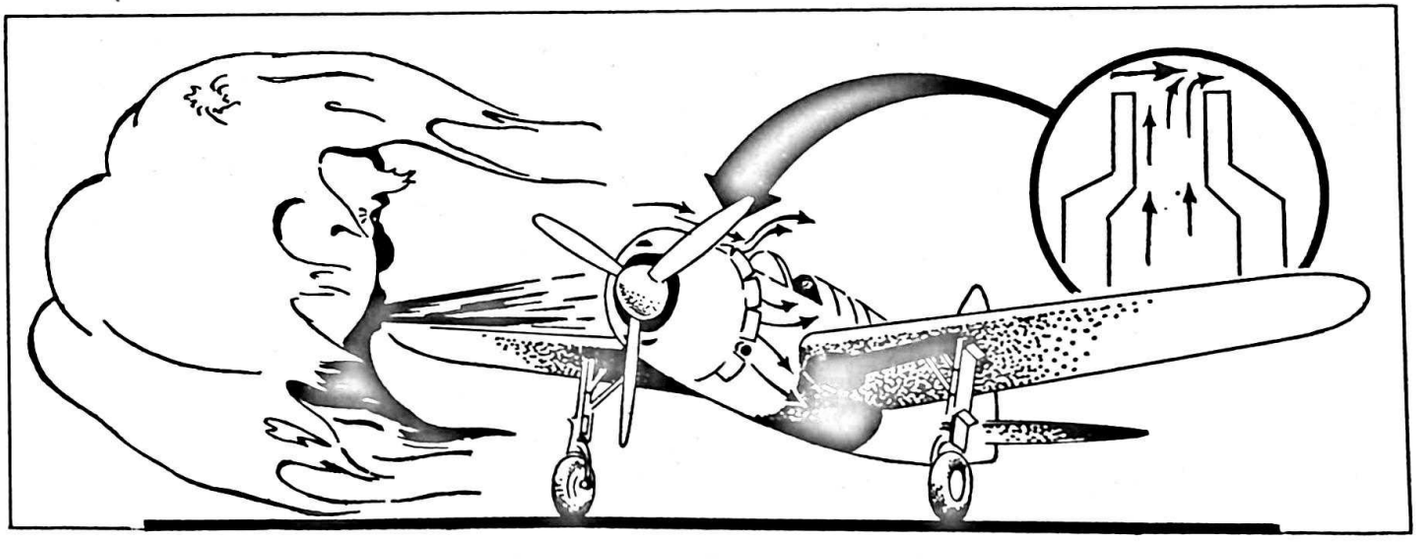
31 Ice formation will act in the same way as a gradual closing of the throttle since it restricts the air-flow more and more as ice fills the induction system. Normally ice will cause a richening of the mixture due to the restricting of the air-flow; however, if the ice forms on the discharge nozzles and prevents full flow of fuel, the action will be that of leaning out.

32 Remove carburetor ice by the application of carburetor pre-heat fluid or de-icing system. Ice can sometimes be removed from the induction system of turbosupercharged installations by increasing power with the turbosupercharger, closing the intercooler shutters or a combination of both. In this manner advantage is taken of the heat generated by compressing the entering air. However, care should be taken to prevent the carburetor air temperature from going above 35°C (100°F) since detonation may result. Also leaning out must be avoided when resorting to this method of de-icing.

VAPOR LOCKS **33** Vapor in the fuel lines may be removed by disconnecting the line and allowing the fuel to drain. Vapor in the carburetor may be removed in Bendix-Stromberg carburetors by removing two plugs on the top of the carburetor. Fill the carburetor by pumping up the pressure until the fuel flows from the holes. Then reinstall the plugs. In the case of

carburetor vapor vents being clogged it will be necessary to clean the system. Refer to the carburetor manufacturer's instructions.

EXCESSIVE GROUND OPERATION **34** High cylinder head temperatures will result from running the engine for prolonged periods of time on the ground. This type of operation should be held to a minimum at all times and the airplane should be headed directly into the wind to get the maximum cooling effect and the proper distribution of cooling air over the entire engine. Cowl flaps should be open at all times during ground runs to allow maximum dissipation of engine heat. The cowl flaps should also be left open after stopping the engine so as to take full advantage of the cooling effects of the "chimney" action of the cowl. It should also be noted that during ground operation, cylinder head temperatures are not always an indication of the most critical conditions existing in the engine or its accessories. Often while cylinder head temperatures appear to indicate that the cowl flaps could be closed, rocker boxes, ignition harness, and shock mounts are at high enough temperatures to cause damage. Therefore, KEEP THE COWL FLAPS FULL OPEN AND HEAD THE AIRPLANE INTO THE WIND FOR ALL GROUND OPERATION.



LUBRICATION

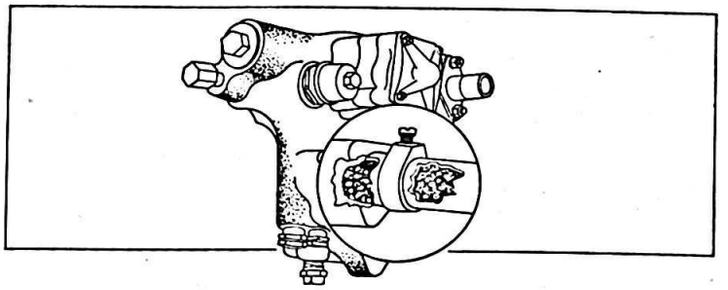
GRADE OF OIL **35** Regardless of climatic conditions, the oil specified for the engine should be used. Other grades of oil may lead to improper lubrication and the resultant part failures. An oil with too high a pour point (viscosity) congeals in cold weather with the result that no oil will be supplied to moving parts. Oil with low viscosity offers insufficient lubrication for moving parts. Never mix two or more brands of oil since the brands may have different chemical compositions, the combination of which reacts unfavorably in the engine.

HIGH OIL TEMPERATURE **36** High oil-in temperatures, experienced during operation at low atmospheric temperatures, can usually be traced to congealed oil in the oil cooler cores which restricts the circulation of oil through the cooler and causes the cooler pressure relief valve to bypass the oil across the cooler directly to the tank. In effect this removes the main oil cooling unit, the cooler, from the oil system. When the condition is encountered, it is recommended that the oil cooler shutters, if present in the installation, be closed to restore circulation through the cooler.

37 Operating conditions under which high power climb at low speeds and high atmospheric temperatures are attempted are also conducive to excessive oil-in temperatures. In most cases this can be alleviated by increasing climbing air-speeds, and, if possible, reducing power.

38 Some difficulties with high oil-in temperatures have been traced to the use of lower than specified engine lubricating oil which increases the flow rate through the engine. The resultant high flow rate cannot be handled satisfactorily by the oil cooling system.

OIL FOAMING **39** Air bubbles or foaming in the oil-in supply line displace quantities of oil in the oil pump that are necessary to maintain proper pressure. Air leaks in the oil-in line will also have the same effect. Foaming will result from contamination of the oil supply either from the mixing of different brands of oil or from the failure to remove completely water-mixed cleaning solutions when cleaning the oil tanks, lines, or engines. Oil tank design may also cause oil foaming. In other cases, remove all oil, clean the system, and replace



with the proper grade of oil. Repair or replace all leaking parts.

EXCESSIVE OIL CONSUMPTION **40** Excessive oil consumption, attributed to a number of factors as described in the chart, presents serious operational difficulties during flight particularly if no correction can be made during flight and no landing is possible. Prevention of excessive oil consumption is mandatory.

41 Inspect the magnetic sump plug and oil strainers regularly for signs of metal particles which may indicate failure of parts. Careful analysis of any particles found will indicate whether or not the engine needs disassembly for repair or replacement of parts.

42 Piston ring wear due to the entrance of foreign material into the cylinder assembly or to operation at close to detonation conditions will also increase oil consumption. The importance of operating and maintaining carburetor air filters correctly and keeping all engine openings covered when dusty conditions prevail cannot be overemphasized. Carburetor air filters should be used at all times on the ground in dusty conditions and duct or port covers of correct size should be installed in all openings to protect the engine from dust storms and prop wash from other ships when the engine is not being used. Attention to the servicing of the filter elements is essential to correct operation of the filter unit under dusty conditions.

43 Breather oil loss and internal or external oil seal leaks also increase oil consumption. Breather oil loss can also result from oil foaming and from improper functioning of breather passages. Worn or improperly installed internal oil seals require replacement.

SECTION VI

ADJUSTMENT, REPLACEMENT, AND MINOR REPAIRS

The work outlined in this section pertains to accessible parts of the engine such as cylinders, carburetors, magnetos, etc.

In making minor repairs or replacing certain parts, it is sometimes necessary to remove adjacent parts that are in no way related to the part under consideration. Instructions for the removal and installation of accessible parts of the engine are included under their separate headings. It is assumed that the mechanic will refer to the respective instructions outlined in this section for all related procedures. For ease of reference, the installation procedure is given directly after the removal procedure. All information regarding accessories should be obtained from their respective manufacturer's instructions.

GENERAL PRECAUTIONS There are certain special precautions to observe in removing and replacing or reinstalling every accessible part of the engine.

DISASSEMBLY AND REASSEMBLY OF PARTS—Tap lightly with a rawhide, fiber, or plastic mallet to remove an accessory or an accessory drive housing from the engine crankcase or to separate the housing sections. The same type of mallet may be used in reinstallation, as required. Tap lightly on a fiber or brass drift, where necessary, in the disassembly or reassembly of small parts. Do not use a screwdriver for any of the above mentioned operations.

CLEANING OF PARTS—Wash all separate parts upon completion of the dismantling and disassembly operation. The Wright Aeronautical Corporation recommends the use of unleaded gasoline or Stoddard Solvent (Varsol) for cleaning purposes. Be sure to soak sintered bushings in hot oil after washing. As washing of the various parts is completed, each part should be dried thoroughly with compressed air. If the parts are to remain unused for any length of time, slush them with slushing mixture, Aeronautical Material Specification No. 3072 or No. 3075. Do not wash the accessories with any liquid solvents or cleaners except as recommended by the respective accessory manufacturer.

ENGINE PROTECTION—Cover or plug all openings to prevent dirt, dust, or any small parts from falling inside the engine. Metal plates that snap in place in the intake pipe and exhaust openings are available, as listed in section VIII. A metal or wood plate for the carburetor induction passage can be made by the operator. Dummy plugs should be installed in the cylinders immediately upon removal of the spark plugs.

INSPECTION—Inspect the condition of all parts that are to be installed on the engine and make sure that all oil passages are clear. Check all spring tensions, oil seal ring gaps, piston ring gaps and side clearances, and clearance between parts, referring to the Table of Limits for the correct values. Inspect spare parts prior to assembly to ensure that all oil passages are clear.

PREPARATION FOR REASSEMBLY AND REINSTALLATION OR REPLACEMENT—Make sure that parts are thoroughly clean and free from grit and dust before being assembled in the engine. Wash in an approved cleaning agent and dry with compressed air as described previously, to remove slushing mixture. Wipe parts with a clean, dry, lintless cloth.

Wipe ignition cables requiring cleaning with a clean, dry, lintless cloth. Terminal contactors should be removed from the cables and washed in acetone. Reinstall absolutely dry. Coat all metal-to-metal mating surfaces in the ignition cable harness and magnetos with a light film of petrolatum, taking care not to get any petrolatum on the ignition cables.

Apply a coating of clean engine oil to all moving parts unless some other lubricant is specified in the text. In lubricating gears, couplings, and shafts, be sure to include internal splines. Refer to the paragraphs under ROCKER BOX PRE-OILING in this section when installing rocker box covers or rocker arms.

If any of the following parts are removed from the engine, replace with new parts of the same type at installation: Gaskets, rubber packing, rubber or neoprene oil seals, rubber hose connections, oil seal rings, circlets, lock washers, cotter pins, palnuts, and lock wire.

SELECTION AND SECURING OF ATTACHMENTS—In the various procedures described in this section, reference will be made to the locking devices generally in use on current production engines. Unless otherwise notified, secure all parts to the engine with the same type of attachments and safety devices that were originally found on removal of those parts. Finish each step in the process of assembly as the work progresses. Do not leave a bolt

loose or a nut unsafetied with the idea of coming back to it later.

Never slack off a nut in order to line up a slot in the nut with the cotter pin hole in the bolt or stud. Replace it with another nut if it cannot be tightened to line up within the required torque limits. Screw down all nuts or cap screws finger tight, then tighten evenly, observing the torque values as specified in the Table of Limits.

Select cotter pin size as specified for the nut to be installed. Always install the head or loop end of the cotter pin to fit in the slot of the nut, not across or outside of the slot, and bend the ends, one up and back over the bolt or stud end, the other down and flat against the hexagon flat.

When lock wire is required, use stainless steel wire on all external and internal engine parts. The wire should be twisted tight enough so that vibration will not cause the wire to chafe and break, but not so tight that the metal will be stretched and the elasticity of the wire destroyed. Never use pliers on any portion of the wire except the ends. Bend down ends of lock wire for personnel safety.

Many of the external fastenings on Cyclone 9HC engines use elastic stop nuts or lock nuts as a locking device while others use plain nuts with palnuts or castellated nuts with cotter pins or lock wire. Make sure the stud or bolt on which the elastic stop nut is to be installed is clean and free of nicks and burrs. This is particularly important if a cotter pin hole is drilled in the stud or bolt. Studs must show a minimum of 1½ threads outside of the fiber portion of the nut when the nut is in place. The heat limitation imposed on elastic stop nuts is 191°C (250°F) and under no circumstance must they be used on internal engine parts or to secure rocker box covers. Elastic stop nuts may be reinstalled until they can be screwed down by hand. The self-locking qualities of an elastic stop nut can be rejuvenated by placing the nut on a flat surface and hitting it lightly with a hammer until the fiber is compressed.

TORQUE WRENCH A torque indicating wrench should be used when tightening nuts or cap screws and the tightening torque values listed in the Table of Limits should be observed. See figure 19.

Observe the following precautions when using a torque wrench:

With one hand, hold the pivoted handle at right angles to the turning axis of the nut being tightened in such a manner that the end of the handle toward the indicator does not touch the bending member of the wrench. Use a steady pull. Support the head of the wrench with the other hand, insuring that no pressure is placed on either the indicator or bending member. When the torque wrench is used in conjunction with a special wrench, the combination must be such that the socket of the torque wrench is on the turning axis of the nut since an offset combination will give an erroneous reading. Torque wrench extensions are calibrated for use with specific wrenches. They must not be used with wrenches bearing other tool numbers. Directions for reading the torque value on the wrench scale are stamped on each extension.

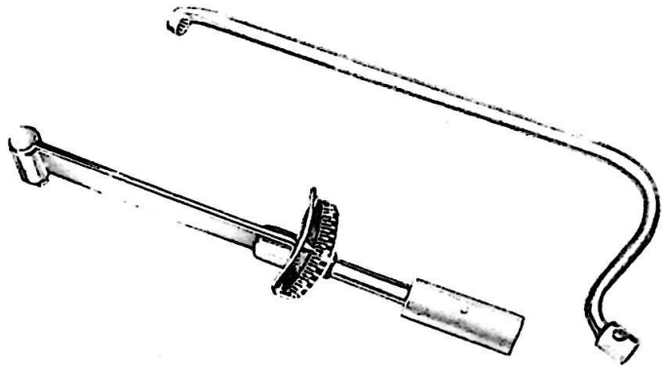


Figure 19—Torque Wrench and Adapter

CYLINDER HEAD AIR DEFLECTORS REMOVAL—Detach the spark plug terminal elbow from the rear spark plug and place a protector over the terminal contactor. Lift the spark plug conduit out of its channel in the deflector.

Detach the deflector from the cylinder by removing the palnut, nut, and washer from the through bolt at the rear of the cylinder head and the two fillister head screws and washers at the rocker box boss. See figure 20.

NOTE: Although cylinder head air deflectors are interchangeable at original assembly, it is advisable to mark them for reinstallation on their respective cylinders.

INSTALLATION—Place the air deflector in its approximate position on the cylinder head, slipping the hole at the rear of the deflector over the end of the through bolt. Loosely install the washer and nut on the through bolt. Loosely install the two fillister head cap screws and washers through the deflector at the rocker box boss. Tighten all attachments evenly. Secure the nut with a palnut and lockwire the two fillister head screws.

Place the spark plug conduit in the deflector channel and connect the terminal contact to the spark plug.

Figure 20—Head Air Deflector Removal

INTERCYLINDER AIR DEFLECTORS

REMOVAL—Remove any obstructing lines or parts such as intake pipes, propeller governor control, or magneto blast tubes. Remove the plate and grommet from the stud holding the deflector at the rocker box cover extensions. See figure 21. Remove the elastic stop nut and washer from the through bolt securing together the intercylinder air deflector and the lower clamp. Disengage the springs linking the sides of the deflector to the adjacent air deflectors and withdraw the deflector rearward.

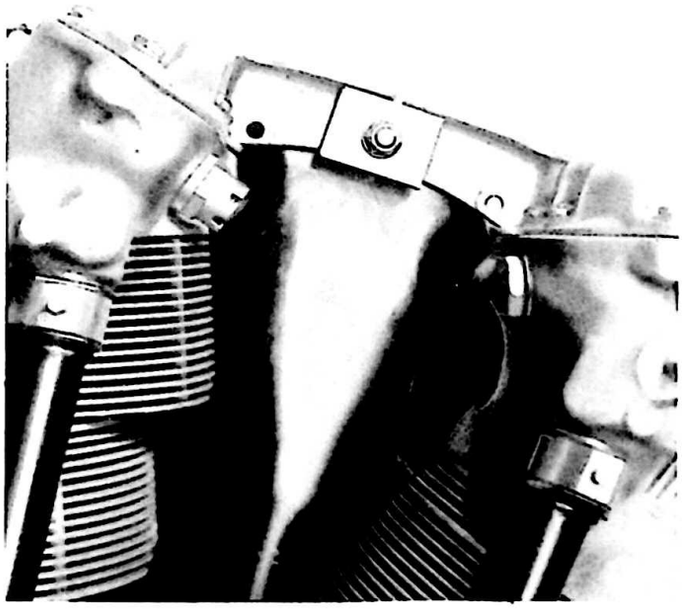


Figure 21—Intercylinder Air Deflector Plate and Grommet

To remove the duct deflectors, if employed, it will be necessary first to remove the air scoop. Remove the elastic stop nut which secures the air scoop to its attaching stud on the duct deflector and disengage the Dzus fastener at the opposite end. Remove the spacer separating the air scoop from the clamp. To remove the duct deflector, first remove the intake pipe. Remove the grommet-and-plate assembly and lower clamp; then withdraw the duct deflector rearward.

To remove the intercylinder air deflector No. 5-6 detach the deflector from the rocker box cover extensions and remove the cap screw and washer securing the deflector to each arm of the sump.

INSTALLATION—Make sure the lower clamp attaching bolt is inserted through the deflector and that the spacer is screwed down tightly on the bolt.

Place the grommet over the rocker box cover extensions and line up the deflector so that the stud projects through the grommet. Install the plate over the grommet and loosely install a washer and elastic stop nut.

Place the lower clamp over the bolt in the deflector so that the ends of the clamp rest on the tapered fins of the cylinder barrel. Secure with a washer and elastic stop

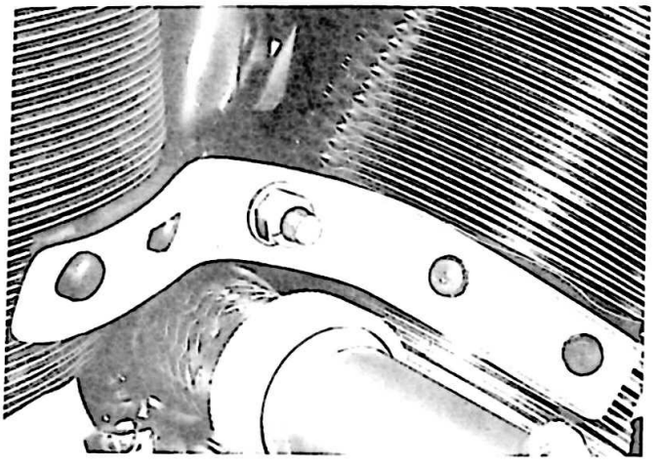


Figure 22—Lower Clamp Installation

nut. Tighten the nut at the rocker box extension end. See figure 22.

Engage the springs that link the sides of the deflector to the adjacent intercylinder air deflectors. See figure 23.

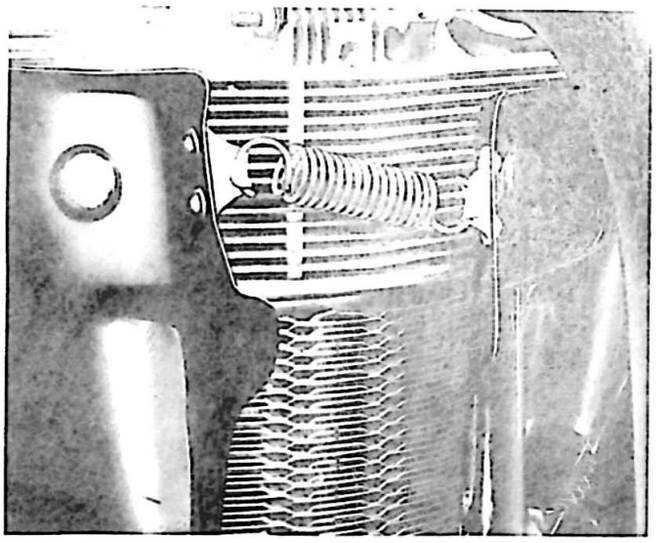


Figure 23—Deflector Spring Lock

Reinstall any parts or lines removed for the intercylinder deflector removal.

Install a duct deflector with the grommet-and-plate assembly at the rocker box end and the clamp at the crankcase end. Secure the clamp with an additional spacer. Position the airscoop on the deflector and secure with an elastic stop nut and washer at the flange end. Engage the Dzus fastener at the opposite end of the airscoop. See figure 24.

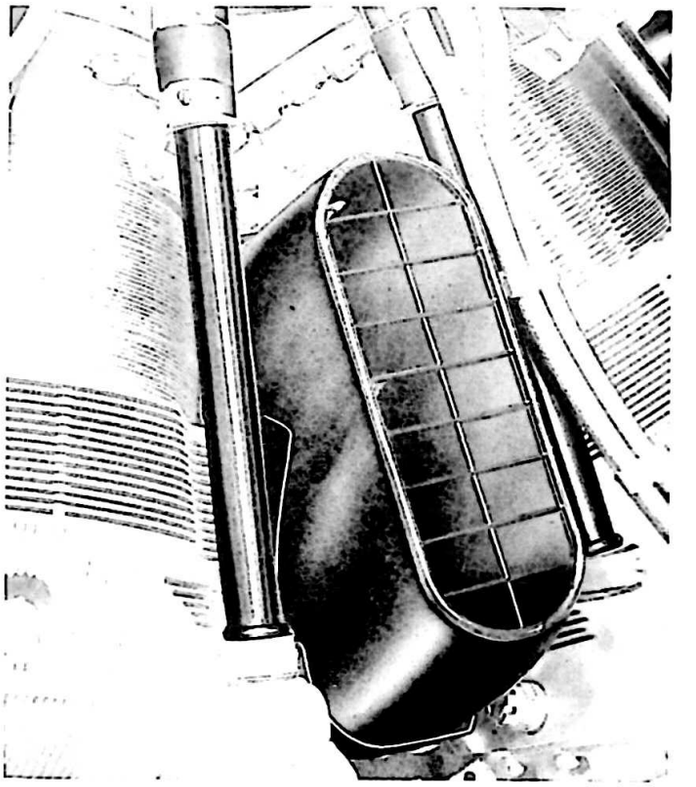


Figure 24—Airscoop Installed on Duct Deflector

Install the air deflector No. 5-6 with the grommet-and-plate assembly at the rocker box end and a cap screw and washer securing the deflector to each arm of the sump. Tighten all attachments and lockwire the cap screws.

INTAKE PIPES REMOVAL—Loosen the packing nut at the crankcase end of the intake pipe with special wrench, Tool No. 803882, and handle, Tool No. 81403. See figure 25.

Remove the three cap screws and shakeproof lock washers at the cylinder end. Withdraw the intake pipe. Remove the intake pipe packing and packing nut. Discard both the flange packing and intake pipe packing. Install cover, Tool No. 804351, over the cylinder intake port and cover, Tool No. 800907, in the supercharger front housing.

INSTALLATION—Use a new packing at each end. Insert the intake pipe into the supercharger front housing. Make certain not to mutilate the packing in any way. Install a gasket under the attaching flange at the intake port parting surface. Install the three cap screws with shakeproof lock washers. Tighten the cap screws evenly. Tighten the packing nut at the crankcase end using special wrench, Tool No. 803882, and handle, Tool No. 81403.

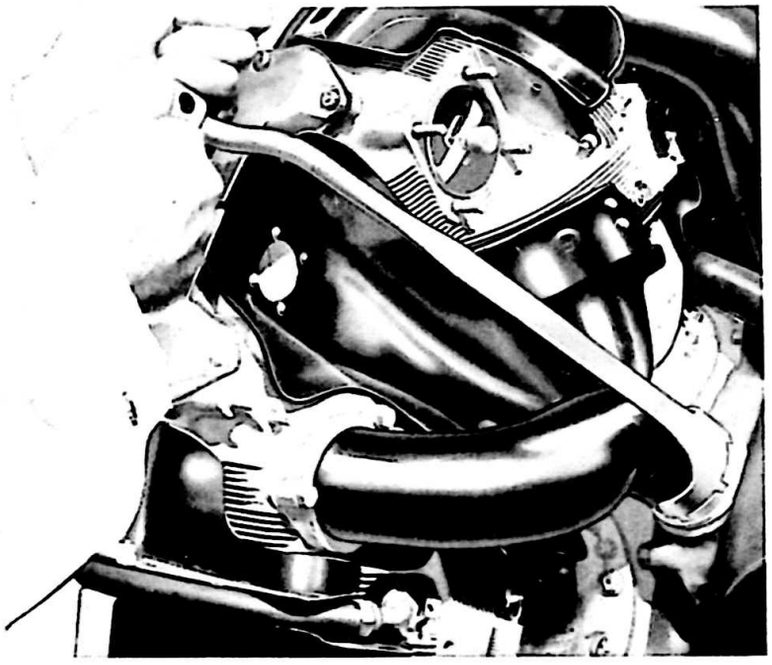


Figure 25—Loosening Intake Pipe Packing Nut

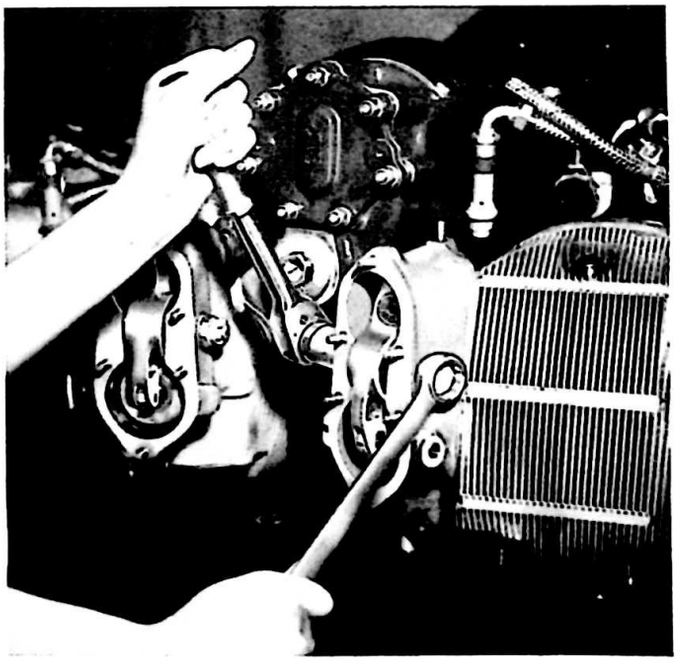


Figure 26—Loosening Rocker Arm Hub Bolt Nut

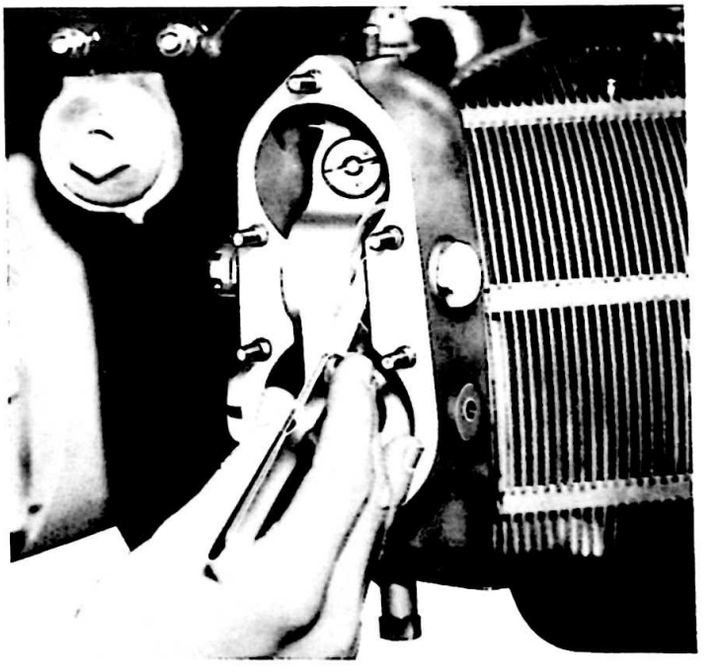


Figure 27—Check Rocker Arm Side Clearance

ROCKER ARMS REMOVAL—Remove the plate and grommet joining the intercylinder air deflector to the rocker box cover extensions. Remove the six rocker box cover nuts; remove the lock washers and washers with magnet, Tool No. 84770. Remove cover and gasket.

Loosen the clamp screw so that the adjusting screw may be loosened. Unscrew the castellated nut on the rocker arm hub bolt. See figure 26. Turn the crankshaft using the turning tool, Tool No. 82284, so that the valve is seated and rocker arm rollers are free to turn. Pull out the rocker bolt, removing the spherical seat washer and oil seal at each end.

Lift the rocker arm out and withdraw the push rod by the uncovered ball end.

INSTALLATION—Install the push rod. Position the rocker arm in the rocker box and slide the rocker bolt through its hub. The head of the bolt should be toward the center of the cylinder. Use an oil seal and spherical washer at each end of the bolt.

Check the end clearance between the bearing inner race and the rocker box. See figure 27. If it is over the limit as specified in the Table of Limits, remove the bolt and install a shim on the antithrust side (outer) between the bearing inner race and the rocker box to take up the excess.

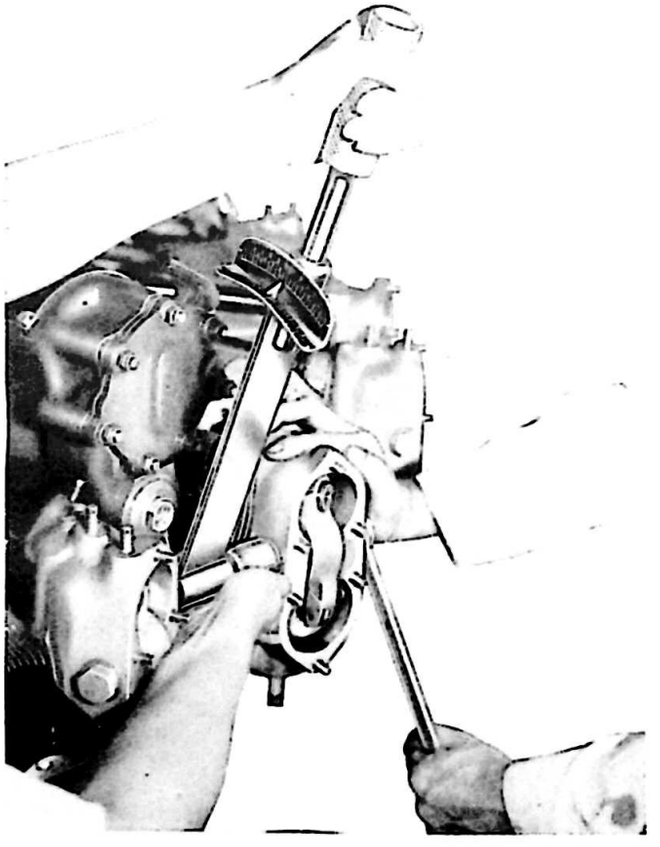


Figure 28—Torque Rocker Arm Hub Bolt Nut

Install the castellated nut and tighten to the correct torque value using the torque wrench, Tool No. 84922. See figure 28. If the cotter pin hole cannot be lined up within the limits of the specified torque, remove the nut and substitute a new washer. Repeat the above procedure if necessary. Insert and secure with a cotter pin.

Adjust the valve clearance. Tighten the clamp screw in the clamp end of the rocker arm.

Lightly coat the rocker arm assembly with oil.

Install a gasket and a cover over the rocker box studs.

Secure with plain washers, lock washers, and nuts. Tighten the nuts at the middle of the cover; then the nuts at the ends. Torque to the value specified in the Table of Limits. See figure 29.

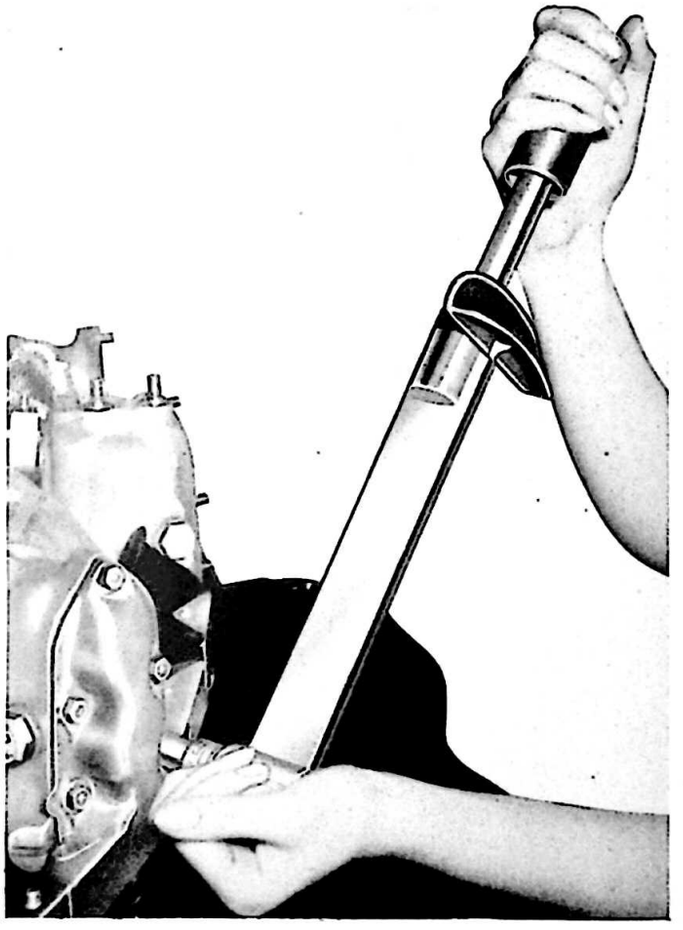


Figure 29—Torque Rocker Box Cover Nuts

ROCKER BOX PRE-OILING Engine oil must be applied to the rocker boxes any time the rocker box covers have been removed.

Liberally coat the rocker box assemblies above the

horizontal center line of the engine with engine oil. Do not fill these boxes as the oil is free to drain down the push rod housing and thereby load the sump.

Fill the rocker boxes below the horizontal center line of the engine by either of the following methods:

Install the rocker box cover and pour approximately a half pint of oil into the push rod housing through the crankcase end.

Pack the engine oil in dry ice until it has the consistency of heavy grease, then fill the rocker box and install the cover.

PUSH RODS AND HOUSINGS

REMOVAL—The following procedure is limited to engines provided with slotted tappet guides. It is given for the purpose of removing push rods and housings without removing the rocker arm hub bolt or disturbing the torque setting which has been applied previously to the rocker hub bolt nut.

Loosen the clips securing the spark plug conduits to the push rod housing. Loosen the two hose connection clamps at the crankcase end of the push rod housing and single hose clamp at the rocker box end of the housing, using the special socket wrench, Tool No. 801122. Use pliers, Tool No. 800687, if the wire type hose clamp is used. Slide the crankcase end hose connection along the push rod housing until the end of the housing is visible.

Remove the plate and grommet linking the intercylinder air deflector to the rocker box cover extensions.

Remove the rocker box cover.

Loosen the rocker arm clamp screw and unscrew the valve clearance adjusting screw all the way out to its stop, using the special screwdriver, Tool No. 81132, or the combination wrench and screwdriver, Tool No. 81900. Make sure the valves are closed. Screw the push rod removing tool, Tool No. 82703, on the extended threads of the valve clearance adjusting screw, insert the handle to serve as a lever, and compress the valve springs. See figure 30. The push rod then may be removed through the front of the valve tappet guide, taking the housing and hose connection with it.

If the special push rod removing tool, Tool No. 82703, is not available or if the tappet guides are not provided with slots, it will be necessary to remove the rocker arm before the push rod is withdrawn from the push rod housing. This procedure is outlined under ROCKER ARMS on page 58. The push rod housing may be pulled out of the hose connections after loosening the hose connection clamps.

INSTALLATION (Rocker Arm Not Removed)—Install a new short hose connection on the sleeve in the cylinder head. Install a new long hose connection flush with the head on the crankcase end of the housing.

Slide the three hose connection clamps over the housing. Oil the push rod ball ends; and install the push rod in its housing.

With the push rod removing tool, Tool No. 82703, com-

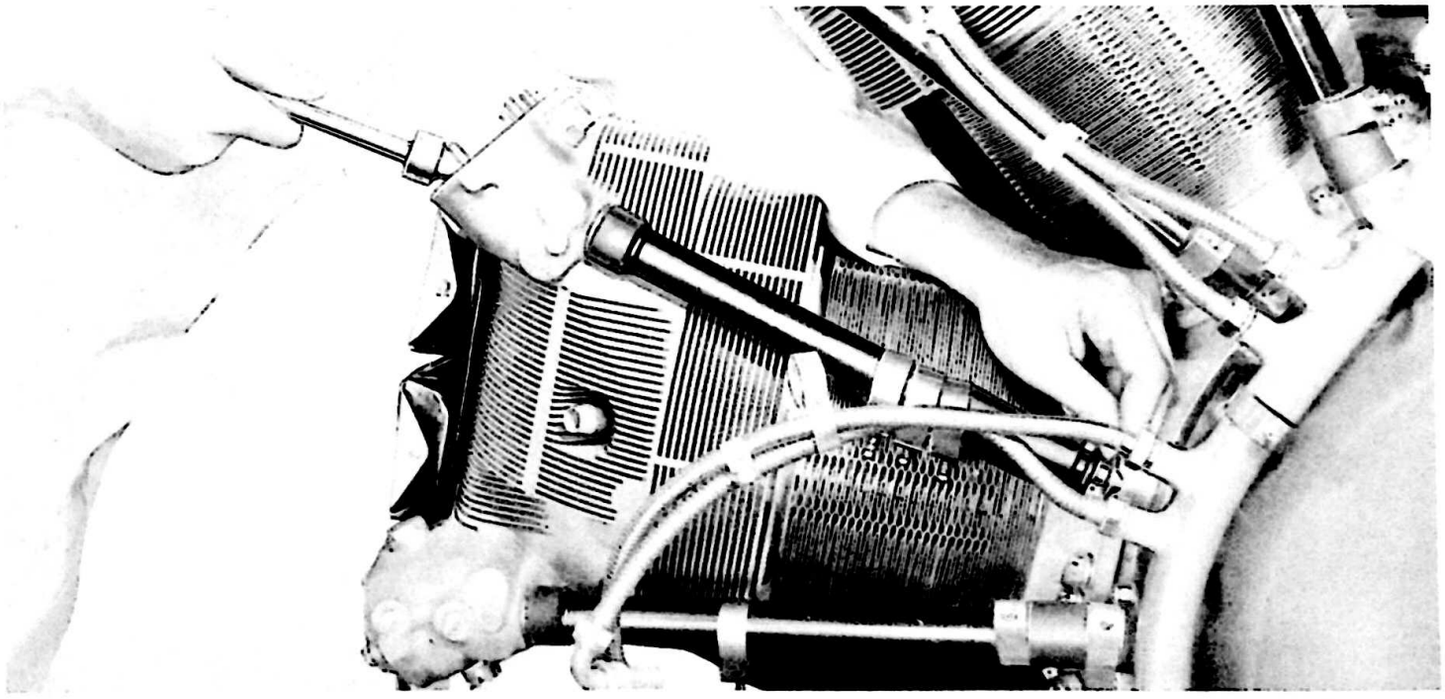


Figure 30—Removing Push Rod without Removing Rocker Arm

pressing the valve springs, slide the push rod housing into its hose connection at the rocker box end and slide the crankcase end of the push rod into the tappet guide.

Slide the crankcase end hose connection over the tappet guide until it butts against the flange.

Locate the two clamps at the crankcase end so that 1/32 inch (.79 millimeter) margin of hose shows beyond the edge of each clamp. Align the clamp screws 30 to 45 degrees off the forward center line of the cylinder wherever possible. Center the one clamp on the short hose connection and align the screw with the cowl attaching studs. Tighten the clamp screws in succession, beginning with the clamp screw nearest the crankcase. Use the special socket wrench, Tool No. 801122.

Adjust the valve tappet clearance and pre-oil the rocker box following instructions on pages 65 and 58, and reinstall the rocker box cover. Connect the spark plug conduits to a push rod housing.

INSTALLATION (Rocker Arm Removed)—Install a new long hose connection and one clamp on the valve tappet guide. Locate the clamp at a position 1/32 inch (.79 millimeter) from the crankcase end of the hose and align the clamp screw 30 to 45 degrees off the forward center line of the cylinder. Tighten the screw using the special socket wrench, Tool No. 801122.

Install a new short hose connection on the sleeve of the rocker box. Insert the housing into the hose on the valve tappet guide and install the other two clamps loosely on the push rod housing. Insert the push rod housing in the short hose connection and force the housing toward the rocker box.

Locate the second clamp from the crankcase end so that only 1/32 inch (.79 millimeter) margin of hose shows beyond the edge of the clamp. Tighten the clamp in line with the clamp already installed on the tappet guide end. Center the one clamp on the short hose, align the screw with the cowl attaching studs, and tighten.

Insert the push rod through the hole in the rocker box into its housing. Replace the rocker arm, check valve clearance, pre-oil, and reinstall rocker box cover. Attach push rod conduit clips to a push rod housing.

VALVE TAPPETS REMOVAL—Remove the loose fitting valve tappet ball socket and mating spring when the push rod and housing have been removed. Move the crankshaft, if necessary, to bring the socket within reach of the fingers.

Remove the palnuts and nuts which secure the tappet guide. If the guide cannot be removed by hand, attach the multipurpose removing puller, Tool No. 802242, with adapter, Tool No. 802726, and remove the guide.

Remove the valve tappet circlet from the tappet and guide assembly, using a fiber drift and lightweight hammer to separate this assembly. Do not attempt to make a circlet jump out of its groove by striking the hollow end of the tappet with a brass drift, thus applying sudden force.

The tappet may be withdrawn from its guide and complete disassembly of roller and bushing effected by pushing the floating pin out of the slotted end of the tappet. All parts of a tappet and guide assembly should be kept together or tagged for future identification in reassembly.

INSTALLATION—Place the tappet roller equipped with its floating bronze supporting bushing in the slotted end of the tappet and insert a floating pin. Slide the tappet

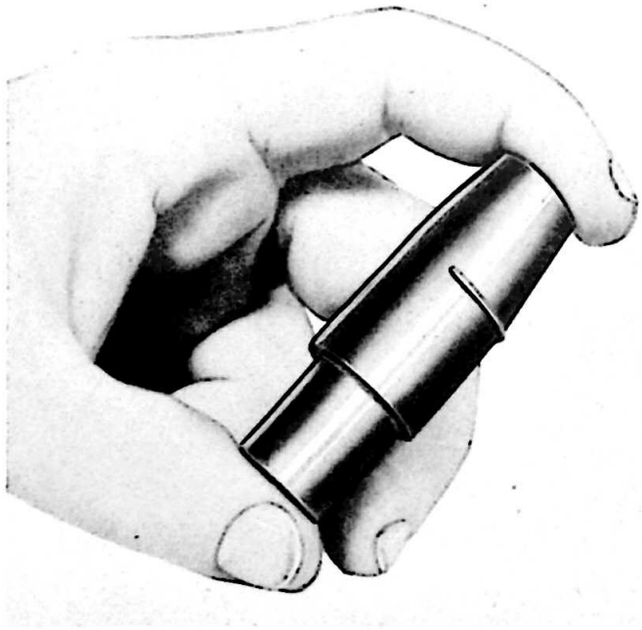


Figure 31—Placing Circlet on Installing Tool

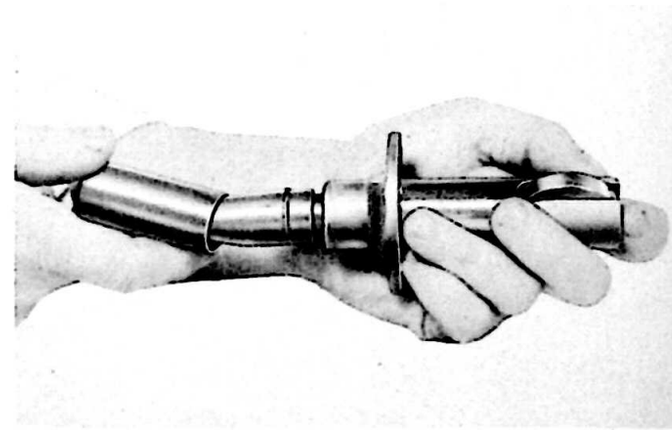


Figure 32—Installing Circlet

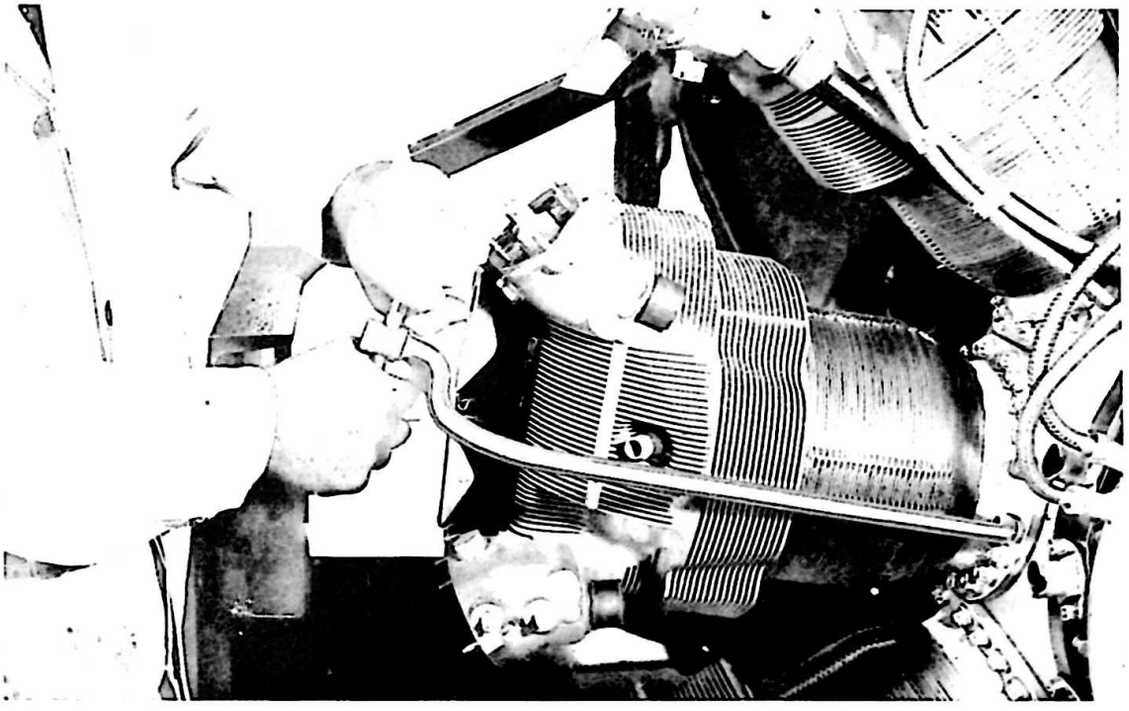


Figure 33—Removing Cylinder Hold-Down Cap Screws

and roller into the tappet guide and install the retaining circlet with the installing tool, Tool No. 803777. See figures 31 and 32.

Install a gasket under the tappet guide flange and insert the tappet and guide in the crankcase. Secure the tappet guide with washers, nuts, and palnuts. Insert the coiled spring and valve tappet socket into the hollow tappet only when the push rod is about to be installed.

CYLINDERS REMOVAL—Remove as much of the exhaust manifold as is necessary for removal of the exhaust stack. Cover the exhaust port using cover, Tool No. 800910.

Disconnect front and rear spark plug ignition terminals and withdraw the spark plug conduits from the cylinder head. Remove a spark plug and install a dummy plug.

Remove the intake pipe and the adjacent intake pipe for accessibility. Cover the ports using covers, Tool No. 804351 for the cylinders, and Tool No. 800907 for the crankcase.

Remove the intercylinder air deflectors from either side of the cylinder.

Remove the rocker box covers. Remove the push rods and housings, valve tappet sockets, and springs.

CAUTION: Make certain the tappet is retained by the circlet.

Remove the oil sump if cylinder No. 5 or 6 is being removed.

Turn the crankshaft until the piston in the cylinder being removed is at the top of its stroke.

Remove the cylinder hold-down cap screws and draw the cylinder straight outward from the engine. See figures 33 and 34. Care must be taken when removing a cylinder that the piston pin plug-type retainers and piston pins do not fall out.

Install a master and articulated rod guide plate, Tool

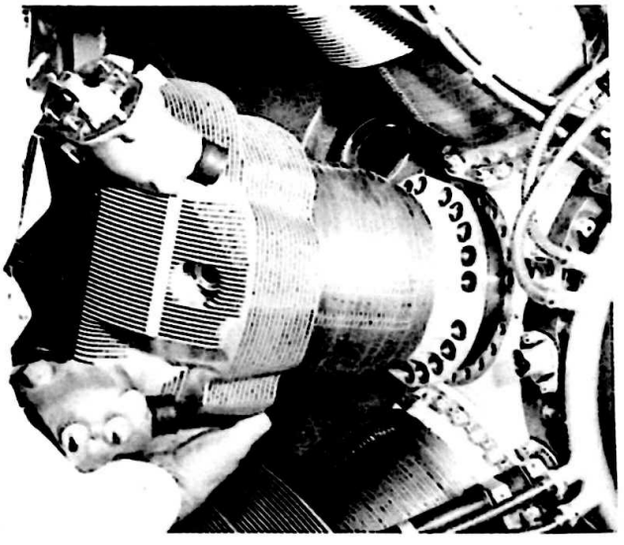


Figure 34—Removing Cylinder

No. 83596, on the cylinder mounting pad. Discard the oil seal packing ring under the cylinder flange and the push rod housing hose connections.

INSTALLATION—If a new cylinder is to be installed, a new cylinder and piston with rings are replaced as a complete assembly. Oil the cylinder barrel bore with castor oil and install an oil seal packing ring under the cylinder hold-down flange. Insert dummy vented spark plugs in the cylinder head.

Turn the crankshaft so that the piston is at the top of its stroke. Lubricate the piston rings with castor oil, avoiding excessive use of the oil as drainage into the combustion chamber may cause fouling of the spark plugs. Make sure the piston rings are staggered properly. See figure 35.

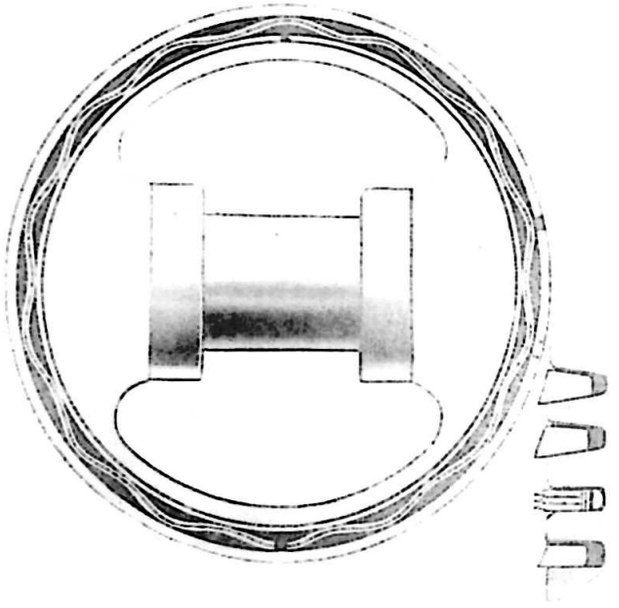


Figure 35—Simplex Piston Ring Arrangement

Remove the master and articulated rod guide plate, Tool No. 83596, from the cylinder mounting pad. Make sure the cylinder hold-down flange and crankcase attaching surfaces are clean and dry.

Compress all the piston rings above the piston pin with the special clamp, Tool No. 803145, and slide the cylinder over the piston. See figure 36. As soon as the cylinder is over these rings, remove the clamp and make certain that both piston pin plug-type retainers are located correctly. Compress these plug-type retainers and the lower ring with clamp, Tool No. 80440, and place the cylinder in its proper location. See figure 37.

Install two special locating cap screws, Tool No. 802177, on opposite sides of the cylinder. Tighten with the offset box wrench, Tool No. 802293, and the torque

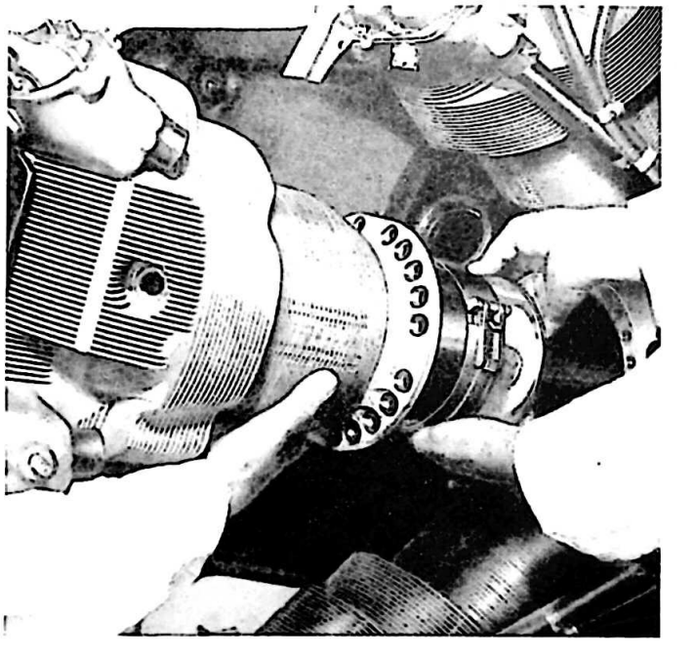


Figure 36—Cylinder Installation with Special Piston Ring Clamp

indicator handle, Tool No. 84922, to a torque of approximately 300 inch pounds (346.20 centimeter kilograms).

Coat the cylinder hold-down cap screws with a sealing compound, moderately and evenly applied. Install 18 of the 20 cylinder hold-down screws finger tight with their spherical seat washers. Two special fire extinguisher bracket hold-down screws may be used in holes No. 10 and 11. For location of these holes see figure 7. First tighten two cap screws which are on opposite sides of the cylinder to 300 inch pounds (346.20 centimeter kilograms). Using the same torque, tighten two more cap

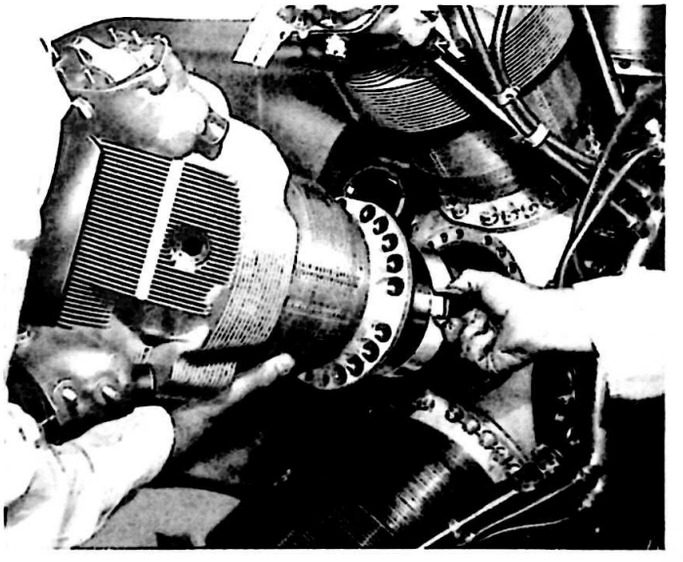


Figure 37—Cylinder Installation with Lower Piston Ring Clamp

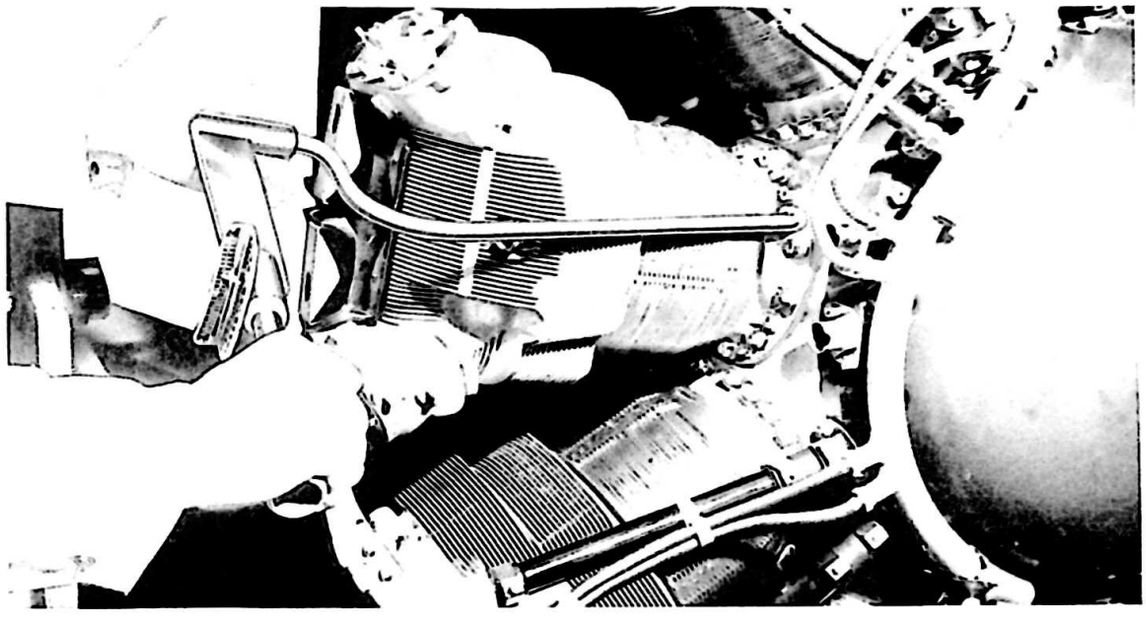


Figure 38—Torquing Cylinder Hold-Down Cap Screws

screws which are on opposite sides of the cylinders and approximately 45 degrees from the last. Proceed in this manner until all cap screws are tightened. See figure 38. Remove the two special locating cap screws and replace with the cylinder hold-down cap screws and spherical washers. Tighten these cap screws with the same torque. Finally, tighten all the cap screws consecutively around the cylinder with the torque as specified in the Table of Limits.

Lockwire the cylinder hold-down cap screws in groups of 5, lacing the wire between the cap screws and twisting the ends together. Install the intercylinder air deflectors. Install the intake pipes that were removed for this operation. Install the valve tappet springs and sockets, push rods, and housings. If cylinder No. 5 or 6 was removed, install the oil sump.

Check the piston for top center position on the firing stroke and set the valve clearance. Pre-oil the rocker boxes and install rocker box covers.

Remove the dummy spark plugs and insert the spark plugs in the cylinder head.

Install the cylinder head air deflector assembly (if not previously installed) and connect the spark plug ignition terminals.

Install the exhaust stacks which were removed and reassemble the portion of the exhaust manifold which was removed or swung out of the way for the cylinder removal. Tighten all joints.

PISTONS REMOVAL—Remove the cylinder following instructions on page 61. Push the piston pin and retaining plugs out of the piston with the fingers. If the pin is tight, it may be removed with the piston pin removing tool, Tool No. 803299. The connecting rod is prevented from striking the crankcase by the master and articulated rod guide plate, Tool No. 83596, previously installed on the cylinder mounting pad.

INSTALLATION—Pistons and rings are replaced as complete assemblies with a replacement cylinder. In checking location and position of the Simplex ring assembly, refer to the chart. See figure 35. Oil the piston pin, connecting rod, piston pin bushing, piston pin retaining plugs, and piston pin bore with clean engine lubricating oil. Turn the crankshaft so that the connecting rod is at the top of its stroke. Install the piston so that the cylinder identification number stamped on the dome of the piston faces the front of the engine. The piston, with piston pin and plug-type retainers, is installed immediately prior to cylinder installation.

VALVES REMOVAL—Place the cylinder, after it has been stripped of all parts except valves and springs, on the cylinder assembly block.

Install the valve spring compressor, Tool No. 802870, placing a strip of fiber or cardboard between the frame and the rocker box parting surface to prevent the tool from scratching the rocker box. Move the lever to its extreme downward position to compress the valve springs.

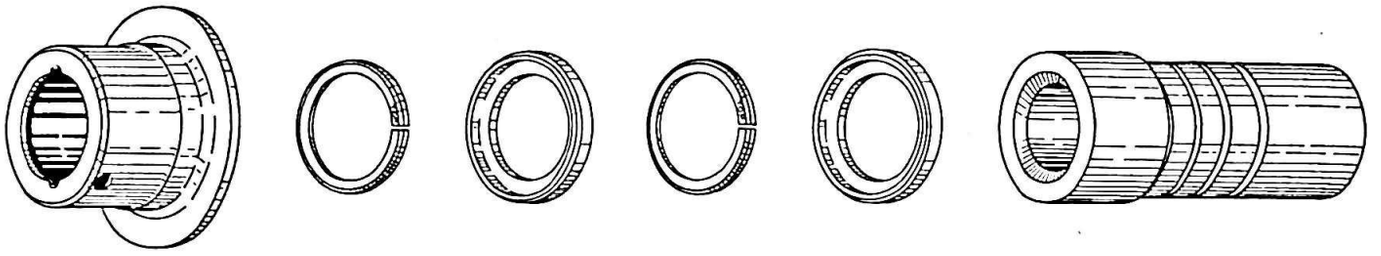


Figure 39—Exhaust Valve Guide Diagram

Remove the split lock now exposed and slowly release the compressor lever. Remove the valve spring compressor from the rocker box.

Lift out the shouldered upper washer, the two valve springs, and the one washer from under the exhaust valve outer spring or the two washers from under the intake valve springs.

Repeat this procedure for the other valve in the cylinder, and remove the cylinder from the block, holding the valves so that they do not fall out of their guides. If more than one cylinder is being disassembled, install markers on the valves as soon as they are removed from the cylinder.

INSTALLATION—Install the valves in the cylinder head, holding them while placing the cylinder on the assembly block.

Install the valve spring supporting washers in their recesses around each valve guide. The spacer retainer on the exhaust valve guide replaces the washer used with the intake valve inner spring.

Install the two valve springs in each recess and place the retaining shouldered upper washer loosely on top of the springs.

Install the valve spring compressor, Tool No. 802870, and compress the valve springs to their extreme downward position. Apply Lubriplate 130-A to the split valve lock and insert it in the valve stem lock groove. Release the compressor lever handle slowly until the shouldered upper washer has seated properly against the outer surface of the lock.

Remove the valve spring compressor and repeat the procedure on the remaining valve.

Lift the cylinder off the assembly block and install the cylinder on the crankcase.

EXHAUST VALVE GUIDE SPACER RETAINER REMOVAL — Remove the spacer retainer from the exhaust valve guide using the special puller, Tool No. 802919. Remove the two oil seal rings and two spacers from the retainer. See figure 39.

INSTALLATION—Center the spacers and rings on the top of the guide in this order: spacer, ring, spacer, ring. Be careful to install the two rings with the side marked TOP facing up. Install the retainer over the rings and spacers pressing the retainer down on the guide. Make certain the retainer is flush against the bottom of the recess in the rocker box.

USE OF TOP CENTER INDICATOR AND TIMING DISK If it is necessary to use a top center indicator and timing disk for timing the engine, proceed as follows:

Use the propeller to turn the crankshaft. If the propeller has been removed, install the propeller shaft turning tool, Tool No. 82284, and two handles, Tool No. 80292. Remove a spark plug in cylinder No. 1 and install the top center indicator, Tool No. 804177. See figure 40. Install the timing disk, Tool No. 801083, with expander, Tool No. 803562, and plug, Tool No. 803563, on engines equipped with a 12-jaw starter coupling. Use expander, Tool No. 801082, and plug, Tool No. 83532, with a 3-jaw starter coupling. Secure it to the starter mounting pad with the regular starter attaching nuts.

The top center indicator should be adjusted as follows: Turn the crankshaft slowly in the direction of normal rotation until the indicator pointer is in the approximate middle of its upward travel. Note the degree reading on the timing disk. (The pointer of the timing disk should have orig-

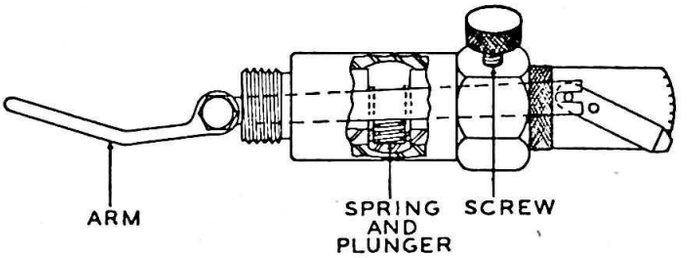


Figure 40—Top Center Indicator

inally been set at any arbitrary figure.) Continue to turn the crankshaft slowly until the indicator pointer has completed its upward stroke and has returned to the point at which the first degree reading was taken. Note the degree reading again on the timing disk. The exact top center position of the No. 1 piston is midway between these two readings on the timing disk.

The pointer on the timing disk should be adjusted as follows: Following the above procedure, turn the crankshaft in the direction opposite to normal rotation for approximately one-quarter of a revolution. Turn the crankshaft in normal rotation until the timing disk pointer indicates the midway point between the original two readings. Set the timing disk pointer to 0 since piston No. 1 is on top center. Adjust and tighten the pointer at this position.

CHECKING VALVE CLEARANCE Remove the six attaching nuts and the rocker box cover. Move the piston of the cylinder in which you are checking valve clearance to the top center position on the compression stroke.

Measure the valve clearance with a .010 inch feeler gage while pressing down on the valve clearance adjusting screw. Move the gage across the roller, not in the direction of rotation.

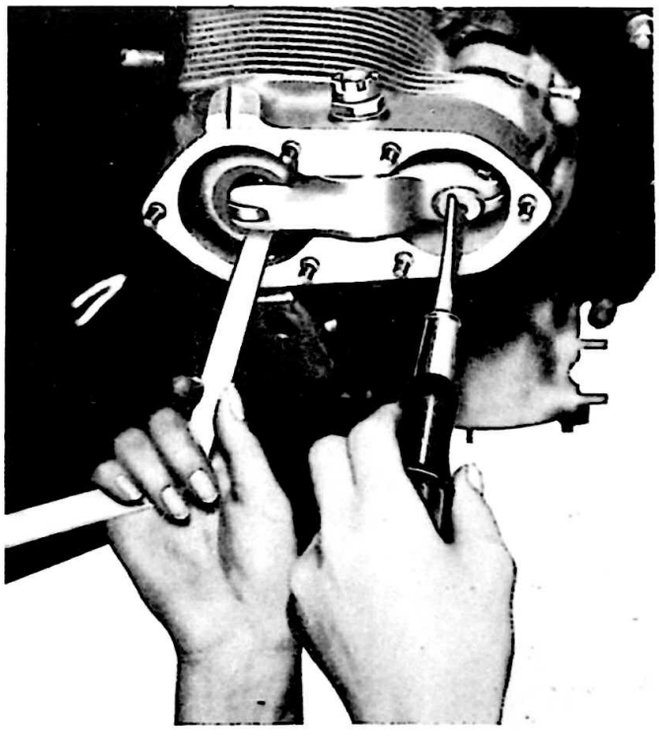


Figure 41—Adjusting Valve Clearance

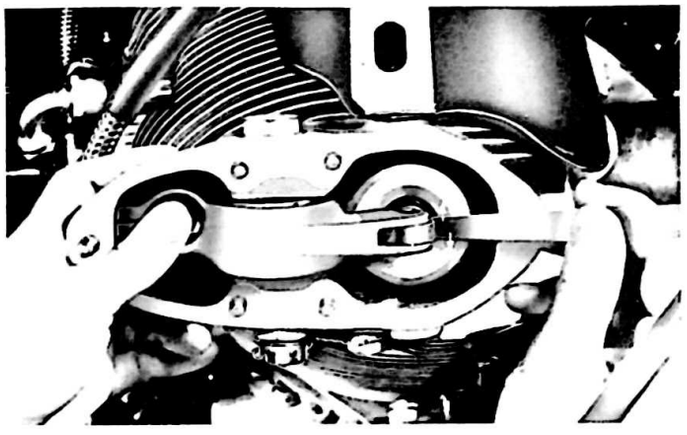


Figure 42—Move Gage across Roller

VALVE CLEARANCE ADJUSTMENT Set the piston of the cylinder in which the valves are to be adjusted at the approximate top of its compression stroke. To obtain this position proceed as follows: Remove rocker box covers, remove one spark plug from the cylinder and use a top center indicator, Tool No. 804177, to determine when the piston is approximately at top center. If a top center indicator is not available, approximate top center position may be determined by visual inspection of the position of the piston through the spark plug insert. The compression stroke may be determined by observing that both valves are closed. (Rocker arm rollers would be free to turn.)

Loosen the adjusting screw lock screw and screw in the adjusting screw of each rocker arm being set for clearance. Use either the special screwdriver, Tool No. 81132, or the screwdriver and wrench combination, Tool No. 81900. Turn down on the adjusting screw until the rocker arm rollers just touch the valve tip. See figure 41. Adjust the clearance between the rocker arm roller and the valve stem tip by turning the adjusting screw in the opposite direction until .010 inch (.25 millimeter) clearance is obtained. Measure the valve clearance with a feeler gage while pressing down on the valve clearance adjusting screw. When taking the measurement move the gage across the roller, not in the direction of rotation. See figure 42.

The three circular marks point out the location of oil passages in the valve clearance adjusting screw. To prevent ineffective lubrication, these marks must be at least $\frac{3}{32}$ inch (2.38 millimeters) from the slit in the rocker arm. If one of the index marks falls within this distance, valve clearance should be increased until the mark is outside of the $\frac{3}{32}$ inch (2.38 millimeters) limit or a maximum of an additional .007 inch (.18 millimeter). See figure 43.

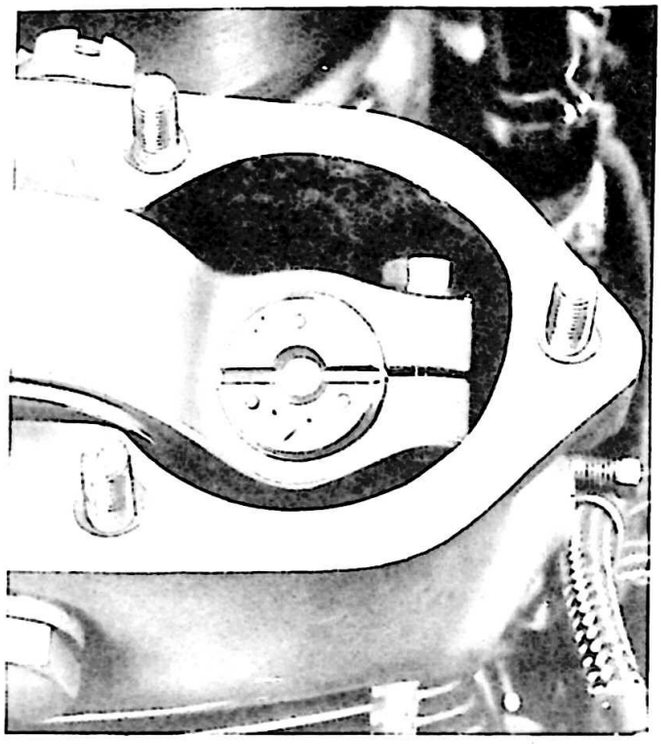


Figure 43—Proper Location of Oil Holes

Securely tighten the lock screw and make certain the adjusting screw is securely clamped in the rocker arm. Continue this outlined procedure in adjusting valve clearances on all cylinders in their firing order. Recheck clearances and reset any clearances that are less than .010 inch (.25 millimeter), or more than .017 inch (.43 millimeter).

CHECKING VALVE TIMING Set the valve clearances of cylinder No. 1 to the timing or running clearance, .075 inch (1.91 millimeters), before checking the valve timing.

After the clearance has been set, turn the crankshaft in the direction of normal rotation until piston No. 1 is approximately 30 degrees before top center of its exhaust stroke. Refer to the degree scale on the reduction driving gear. Then tap the propeller or the propeller shaft turning bar until the intake rocker arm roller is binding against the valve stem, at which point the intake valve is just beginning to open. Note the degree reading on the timing scale. If the cam gears are meshed properly, the valve adjusted accurately, and the check carefully made, the readings obtained should check within ± 5 degrees of the valve timing specification given on the engine data plate. If the readings are not within 5 degrees of the value given, the valve timing should be rechecked. As an additional check after obtaining this reading, continue to tap the propeller or turning bar until the exhaust rocker arm roller is free to turn. (Exhaust valve would then be fully seated.) Note the degree reading on the timing disk. This value should also check within 5 degrees of the value for exhaust valve closing as per the engine data plate. If the degree reading does not fall within the ± degrees limit, the engine must be disassembled.

Upon completion of the check, reset the valve clearances in cylinder No. 1 as previously described.

If for any reason it is not feasible to check the valve timing on the reduction gear timing scale, remove the starter and install a timing disk and pointer on the starter pad. Before checking the valve timing set the timing disk pointer to 0 degrees when piston No. 1 is on top center position. All degree readings should then be taken from the timing disk.

MAGNETOS For service, maintenance, and repair of the Edison-Splitdorf, Scintilla, or Bosch magnetos refer to their respective manufacturer's instructions.

REMOVAL—Disconnect any lines which would interfere with the magneto removal: ground terminal cable, magneto blast tube, supercharger line, if used. The induction vibrator, if employed, is disconnected automatically with the ground terminal.

Before removing the magneto from the engine it will be necessary to remove the distributor block from the magneto. The distributor block, with ignition cables attached, may be used in a replacement magneto of the same type unless the block requires repair. Loosen the couplings at the magneto conduit ends and on the ignition harness crossover. Loosen the ignition cable outlet from the radio shield, if detachable. Remove the distributor block from both magnetos and swing the rear portion of the harness assembly and the attached blocks clear of the magnetos. Secure to any nearby location. Details regarding removal of the distributor block assembly from each of the three magneto types are as follows:

Edison-Splitdorf: Remove the four allen screws securing the radio-shielded distributor block to the rear face of the magneto. If a supercharged magneto is used, be careful not to let fall the baffle plate and gasket assembly which is now loosened from its position between the radio shield and the magneto housing. See figure 44. Non-supercharged magnetos are not provided with this plate-and-gasket assembly.

Scintilla: Remove the magneto coil cover. Withdraw the screws attaching the distributor block and radio shield assembly to the magneto front end plate and lift the assembly vertically from the magneto.

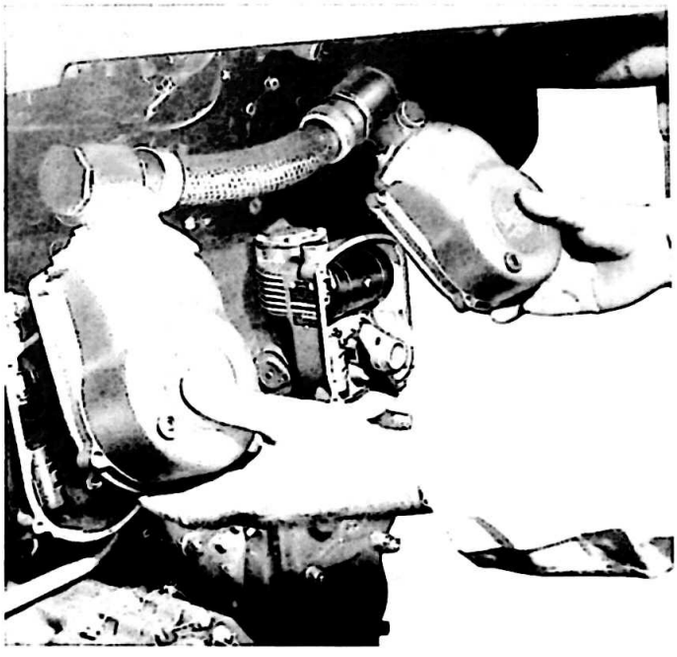


Figure 44—Removing Edison-Splitdorf Magneto Distributor Blocks

American Bosch: Remove the radio shield in halves from the distributor block. Caution—Remove conduit clamp bolt. Loosen the nuts that secure the gear housing just enough to release the edge of the distributor block gasket employed on a supercharged magneto of this type. Loosen the dust cover and raise it slightly toward the engine. Lift the distributor block vertically from the magneto. See figure 45.

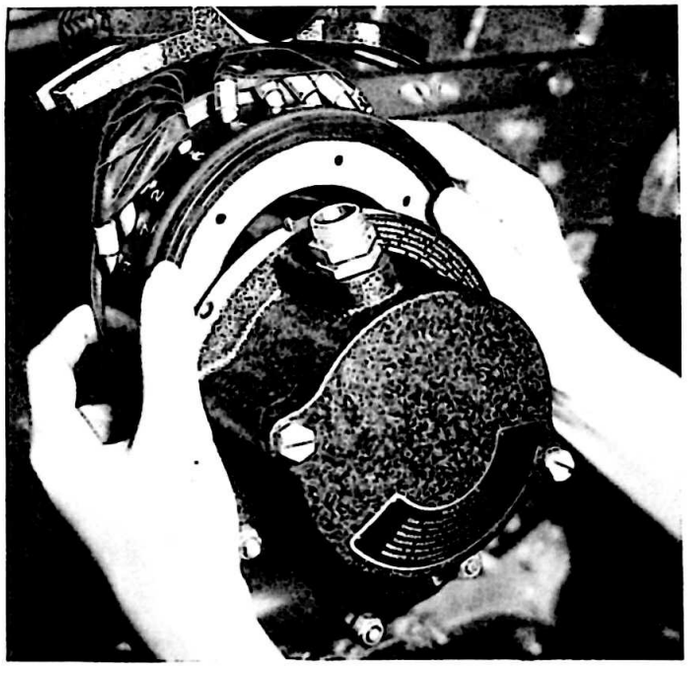


Figure 45—Removing Bosch Magneto Distributor Block

The breaker assembly of the Edison-Splitdorf is uncovered with removal of the radio-shielded distributor block. To uncover the breaker assembly of the Scintilla or Bosch magnetos it will be necessary to remove the breaker covers.

Detach the magneto from the engine by removing the cotter pins, castellated nuts, and washers from each of the three magneto attaching studs. Remove the magneto and gasket.

TIMING AND INSTALLATION—In any of the following procedures the ignition switch should be in the "OFF" position and the mixture control in "CUT-OFF" position. Before installation of the magneto, check the engine data plate for correct degree of spark advance. Remove the timing hole plug to check degrees of spark advance by using the timing scale on the reduction driving gear. See figure 46. Turn the crankshaft with the propeller or, if the propeller has been removed, use the propeller shaft turning tool, Tool No. 82284, and handle, Tool No. 80292. Find top center on the compression stroke on cylinder No. 1. Outline of this procedure is given on page 65. Back off the engine approximately one-quarter turn and then bring forward to take up backlash of gears. Then slowly rotate crankshaft in the direction of normal rotation to the proper spark timing advance as per engine data plate specifications.

It is assumed that the internal timing of a replacement magneto is correct. However, before installing a magneto on the engine, check the internal timing by rotating the

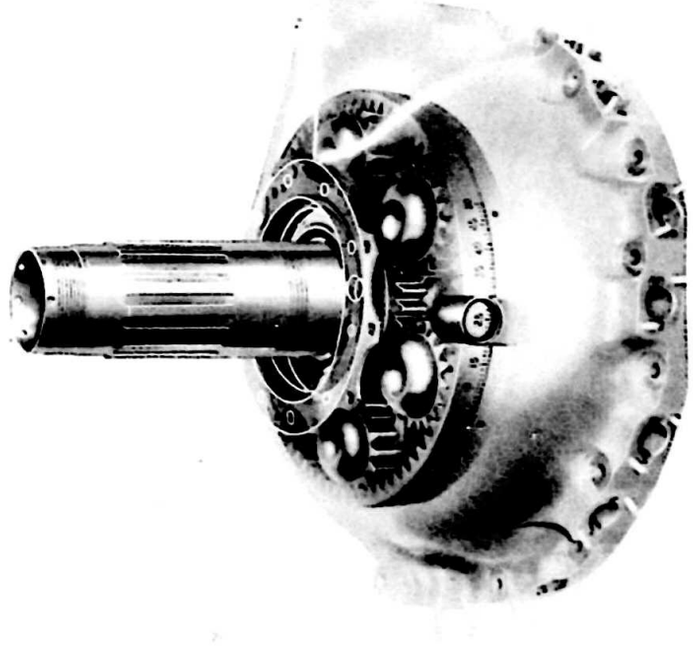


Figure 46—Timing Hole Plug

magneto drive shaft or rotor until the magneto timing marks line up. Use a straight edge for visual inspection of the alignment of these marks. See figures 47, 48, and 49. If these marks do not line up within 1/32 inch (.79 millimeter), obtain a correctly timed magneto.

Compensated magnetos should be timed with the No. 1 cylinder to the No. 1 cam lobe. If the magneto is correctly timed internally, mount it on the engine with flat washers and proper mounting nuts. Tighten the nuts sufficiently to support the magneto firmly on the cover, but not tight enough to prevent adjusting the position of the magneto.

When using a battery operated timing light, the primary

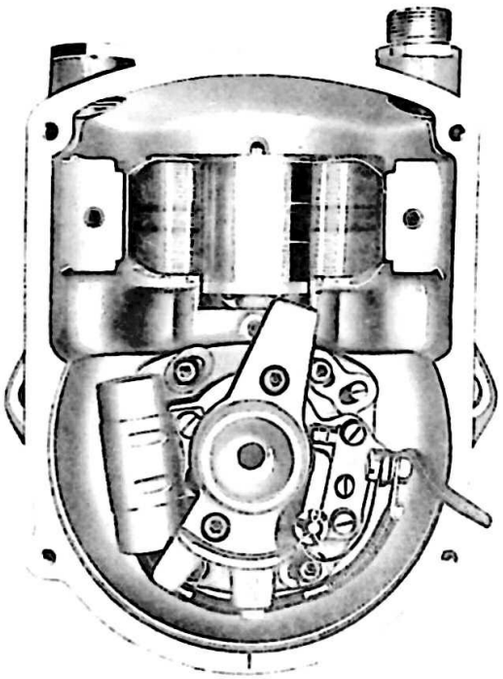


Figure 47—Edison-Splitdorf Magneto Timing Marks

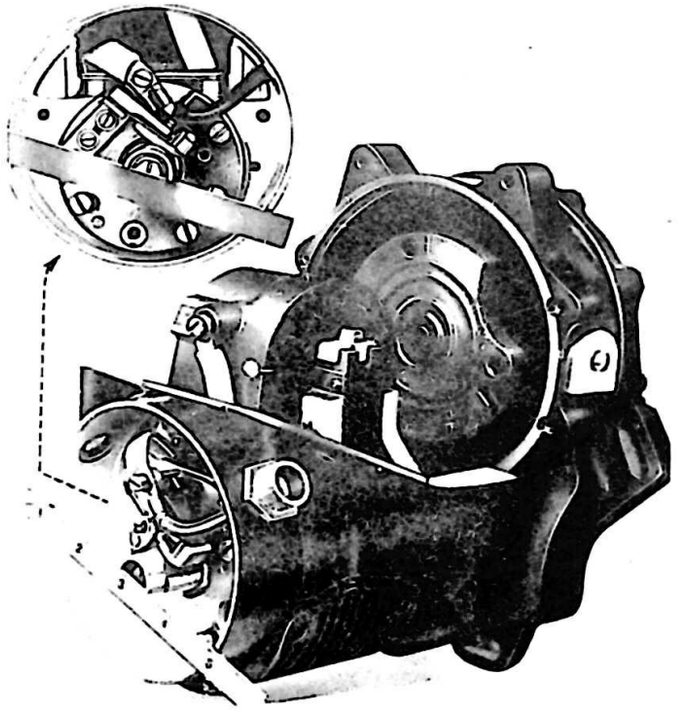


Figure 49—Scintilla Magneto Timing Marks

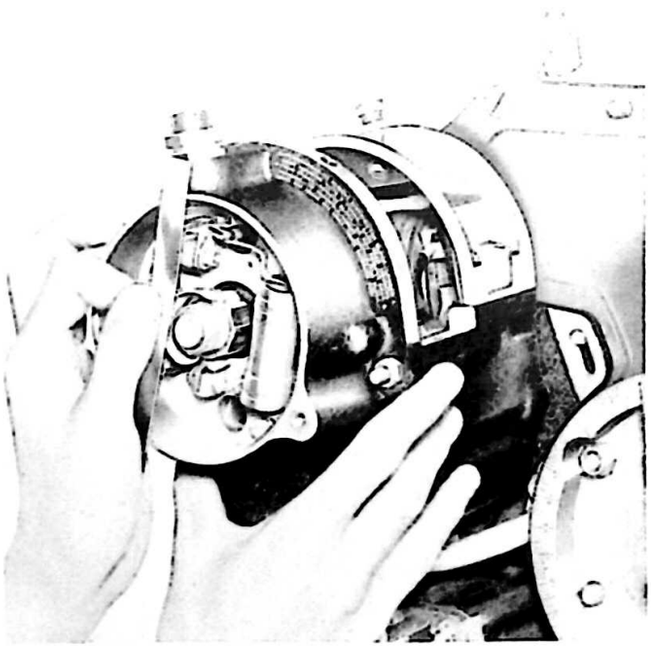


Figure 48—Bosch Magneto Timing Marks

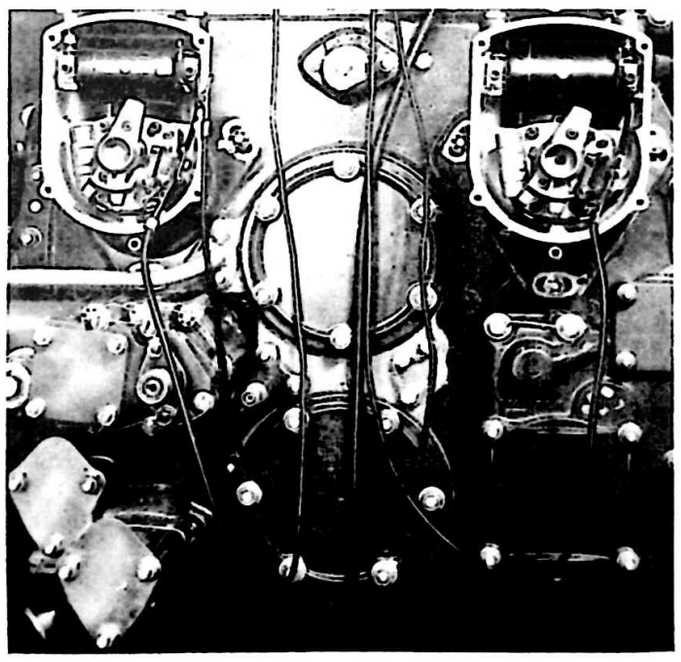


Figure 50—Magneto Timing Synchronization

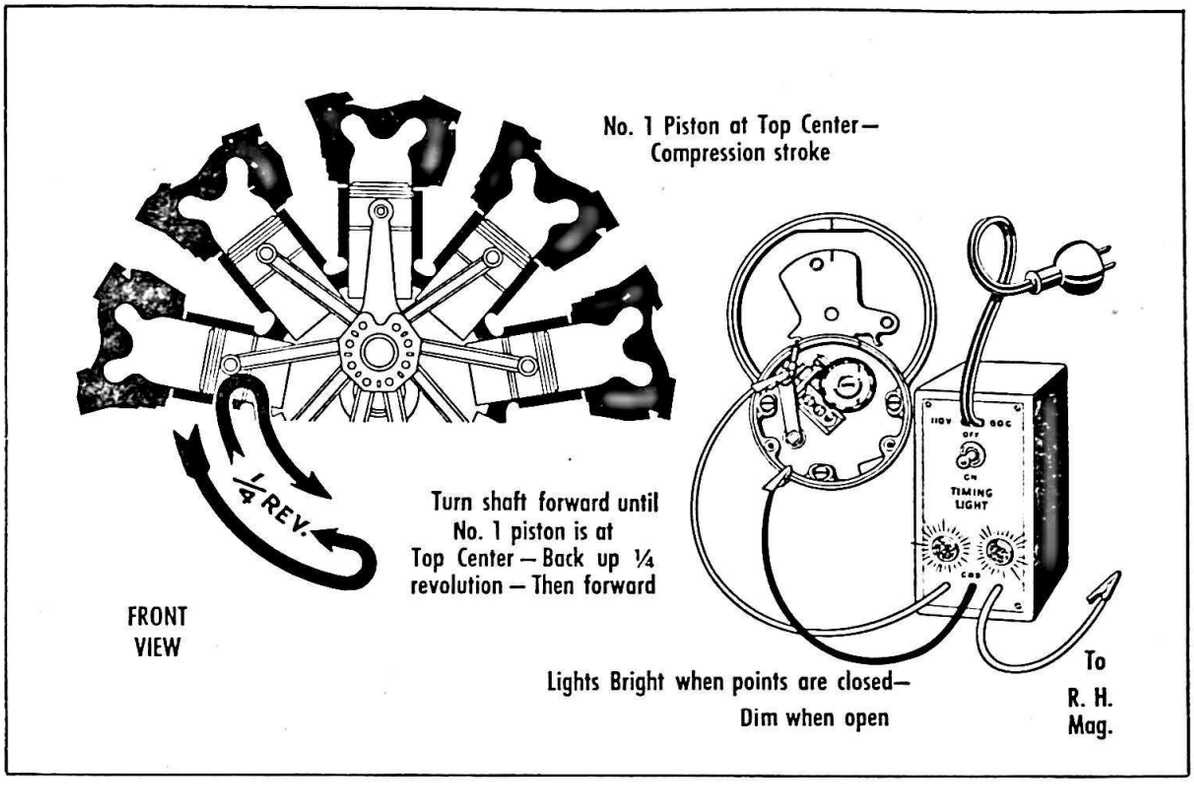


Figure 51—Timing Magnetos to Engine

ground connections must be broken in order to obtain proper light action and to prevent possible demagnetization of the magneto. When using the timing light Scintilla Tool Nc. 11-8511, or its equivalent AC timing light, a primary circuit does not have to be broken. The ignition switch must be turned on. The red leads, or their equivalent, should be connected to the insulated contact points of each magneto and the black lead, or its equivalent, grounded to the engine.

NOTE: Some types of portable timing lights are connected internally so that the light will go OUT when the contacts close and ON when the contacts break. Therefore, for generalization purposes, the primary interest for checking will be a change in the action of the lights.

Minor adjustment can be made by tapping the magneto using a rawhide hammer and moving the mounting flange on the studs until a change in the action of the light occurs. Then tighten the magneto securely. The breaker point setting, as indicated by the timing lights, should be at the correct engine timing position after the mounting nuts have been fully tightened.

If the range of the slots affords insufficient travel to enable the points to open, it will be necessary to remove the magneto. Timing adjustment can be achieved by turning the rotor one revolution until lobe No. 1 is again in position to fire. If proper adjustment cannot be obtained, in this manner, it will be necessary to remove the magneto drive shaft coupling and reinstall it on a different spline position. Replace the magneto on the engine, and, if necessary, repeat this outlined procedure until proper adjustment is made for the point opening.

Synchronize one magneto to the other by means of these timing lights which should have similar action simultaneously. See figure 50. After the final check, back the engine off 90 degrees and slowly turn the crankshaft in the direction of normal rotation until the points open on lobe No. 1; at this point there should be a change in the action of the lights. See figure 51. Check the timing marks on the reduction gear; these should come within one-half degree of engine data plate specifications for correct degrees of spark advance.

A .0015 inch feeler gage may be used instead of timing lights but should be avoided whenever possible, since the timing lights are far more accurate and any disturbance of the points is undesirable. Where feeler gages are used, the same procedure is followed and the tension on the feeler gage should just break loose when the contact points open. It is important that the feeler stock be degreased, cleaned, and dried before it is inserted between the points.

No adjustments should be made with either breaker points or the breaker plate when timing a magneto to an engine.

Complete the installation of the different magneto types as follows:

Edison-Splitdorf: Assemble the radio-shielded distributor block assembly on the rear face of the magneto and secure to the magneto with four screws. If a supercharged magneto is used, the baffle plate and gasket assembly is placed on the flange of the distributor block before installation of the shield on the magneto. When the radio shield has been secured to the magneto, tighten the screws securing the ignition cable outlet to the radio shield.

Scintilla: Install the radio-shielded distributor block in the magneto. Install the coil cover and the breaker cover.

American Bosch: Install the distributor block, with supercharging gasket, in the magneto. Secure the gear housing and the dust cover. Install the radio shield and tighten the ignition cable outlet to the shield. Install the breaker cover.

Tighten all loosened connections in the ignition cable harness assembly. Connect all lines that were removed for removal of the magneto.

Remove any tools from the engine and reinstall any engine parts that were removed for timing purposes.

MAGNETO DISTRIBUTOR BLOCK

REMOVAL—If it is necessary to replace the distributor block, use the following procedure. Remove the block from the Edison-Splitdorf, Scintilla, or Bosch magneto following the applicable instructions under MAGNETOS on page 66. Then detach the Edison-Splitdorf or Scintilla distributor block from its radio shield; or remove the supercharging gasket and insulation plate from the Bosch distributor block.

Back out the cable piercing screws and withdraw the ignition cables from their wells in the distributor block. As each cable is removed, check to see that the number stamped on the washer at the end of the cable corresponds with the number stamped beside its well in the block. Tag each cable with the same identifying number; or check the numbered tags if already installed. These numbers denote the firing order of the magneto and not the cylinder numbers.

INSTALLATION—If a neoprene hose is installed over the cables at the magneto outlet, make sure it is in good condition. The cut-out in the hose should face the front of the engine. Line up the cables relative to their positions in the distributor block. Measure each cable end extending from the hose to make sure it is the proper length to reach its hole. Excess length may be pushed back into the ignition cable harness, or cut from the cable and the washer reinstalled. For installation of the washer, refer to IGNITION CABLES on page 75.

Fill the distributor block wells with Dow Corning No. 4 compound following the instructions under SEALING COMPOUND on page 75. Coat three inches (75 millimeters) of the cable ends with the compound.

Insert one cable at a time, making sure it bottoms in its well. Secure it with the cable piercing screw.

When all cables are secured in the block, test for shorted or open circuits and for correct firing order as described under IGNITION CABLE TEST.

Individual details regarding each of the magneto types are given below. These details apply to the foregoing instructions and also to the assembly of the distributor block in its shield.

Edison-Splitdorf: Hold the distributor block in its approximate position in the radio shield while inserting the cables. After the ignition cable test has been performed, secure the block to its shield with two screws. If a supercharged magneto is used make sure that a neoprene gasket is inserted with rubber cement in each groove in the radio shield. Lock washers are used under the heads of the cable piercing screws.

Scintilla: Lock washers are not used under the heads of the cable piercing screws. If a booster magneto cable is used, it should be inserted in the distributor block hole marked "B" and secured with a cable piercing screw. If this cable is not used, it should be replaced with a two inch (50 millimeters) length of dummy cable (cable with wires removed) secured with a cable piercing screw; or a cable piercing screw can be installed alone with a lock washer. Install the radio shield halves on the distributor block before installation of the block in the magneto.

American Bosch: Install the cable piercing screws with lock washers. Install the insulation plate and supercharging gasket on the distributor block before installation of the block in the magneto.

Complete the installation procedure by installing the distributor block in the magneto following the applicable instructions on page 69.

IGNITION CABLE TEST—Test for a short circuit due to faulty insulation of the cable using a high tension ignition harness tester. For details of this procedure refer to the paragraphs under IGNITION HARNESS, page 45, section V.

To test for an open circuit and to make certain that the cables lead to the proper cylinders, a buzzer or light system is used. Touch the distributor block electrode with one contact and the spark plug end of the cable for the proper cylinder with the other contact. For example, the cable inserted in distributor block well No. 2 goes to cylinder No. 3, which is the second cylinder to fire.

The following table gives the relation between the cylinder and magneto firing order.

Magneto Distributor Block Number	Cylinder Number
1	1
2	3
3	5
4	7
5	9
6	2
7	4
8	6
9	8

The circuit is complete when the buzzer gives a signal, or when the lamp brightens (or dims).

MAGNETO GROUND TERMINAL REMOVAL—Remove the wire lock ring and unscrew the ground terminal nut. Withdraw the shielded ground cable and terminal from its bushing in the magneto.

Unscrew the knurled terminal nut contact spring from the terminal screw through which the ground wire is inserted. Straighten the wire strands from the threaded end of the terminal screw and pull the terminal screw from the cable. The rubber collar and spacer may then be removed from the ground terminal cable. The retaining nut may be left installed on the radio-shielded cable.

INSTALLATION—Slip the spacer and rubber collar over the ground terminal cable. Strip the end of the ground cable insulation for about ½ inch (12 millimeters) and twist the wire strands. Insert the stripped end of the ground cable in the hole in the terminal screw. Count the strands to make sure all have entered, and fan the strands of wire over the threaded end of the screw. Screw the terminal nut with spring on the threaded end of the terminal screw.

Insert the ground terminal into its receiving bushing in the magneto, making sure the spring is properly seated on its contact. Secure with the terminal retaining nut. Snap the spring wire lock ring into the retaining nut slots.

SPARK PLUGS Information on the repair and adjustment of spark plugs may be found in the manufacturers' instructions. Supplementing the above, it should be noted that the thickness of the solid copper gaskets or washer type thermocouples should conform to the following limits: minimum .068 inch (1.73 millimeters); maximum .085 inch (2.16 millimeters) with the following exception. This maximum of .085 inch (2.16 millimeters) is preferred for thermocouple thickness, however, .095 inch (2.41 millimeters) is permissible for thermocouples.

REMOVAL—Loosen the coupling nut at the conduit end of the terminal elbow and the coupling nut at the spark plug end of the elbow. Use the crowfoot wrench, Tool No. 800630, for ¾ inch (19.05 millimeters) hex nut. Withdraw the terminal elbow and shielded terminal contactor from the spark plug.

Remove the spark plug using the socket wrench, Tool No. 84458, for ⅞ inch (2.23 millimeters) hex plug. See figure 52. Replace the plug immediately or insert a dummy plug.

INSTALLATION—Install the spark plug with solid copper gasket or washer-type thermocouple. Prior to installing the spark plugs, clean and reset the spark gaps to .012 inch, plus .002 inch minus .001 inch (.31 millimeter, plus .05 millimeter minus .03 millimeter). Apply Lubriplate 130-A to the shell threads. Be particularly careful to keep the electrodes dry and clean. Tighten the spark plugs to the torque value specified in the Table of Limits.

Inject sealing compound in the spark plug well following the instructions under SEALING COMPOUND on page 75. Insert the shielded terminal contactor in the spark plug

Figure 52—Loosening Spark Plug

well. Secure the terminal elbow by first tightening the coupling nut at the spark plug end and then the coupling nut at the spark plug conduit end. Use the crowfoot wrench, Tool No. 800630, and tighten the nuts so that they are snug. Do not overtighten the nut at the spark plug end. Conduits should be permitted to lie in their relaxed positions during tightening. This prevents breakage from vibration.

Terminal contactors should be wiped clean with a clean, dry, lintless cloth. If the results are unsatisfactory, contactors should be removed from the cables, washed in acetone and thoroughly dried with an air hose before being installed. If cleaning is unsatisfactory, contactors should be replaced. At no time should any cleaning solutions come close to ignition cables.

SPARK PLUG TERMINAL CONTACTORS AND ELBOWS REMOVAL — Detach the spark plug elbow and withdraw the terminal contactor from the spark plug. Straighten out the ignition cable strands which are fanned out around the base of the coiled contactor spring and pull the terminal sleeve assembly from the end of the ignition cable.

Loosen the coupling nut securing the spark plug elbows and withdraw the elbow and rubber grommet.

INSTALLATION—Strip the ignition cable insulation sufficiently for attachment of the terminal contactor spring. If the cable is not long enough for additional stripping of insulation, slide the conduit back from the manifold ring and draw up the cable at this point. Install the spark plug elbow on the end of the spark plug conduit using a grommet in the joint between the two. The rubber center of the metal-and-rubber grommet should be installed within the elbow recess.

It is important to note that spark plug elbows for the front spark plugs have a 70 degree angle and that the elbows for the rear spark plugs have a 110 degree angle. See figure 53.

Fill the spark plug elbow with sealing compound, following instructions under SEALING COMPOUND on page 75.

Twist the strands of the ignition cable slightly and insert the cable into the terminal contactor, with its stripped end extending through the hole at the base of the contactor spring. Count the strands to be sure that all of them have been pulled through. Fan the wire strands and press them into position over the end of the contactor washer nipple with a small screwdriver. See figure 54.

Insert the terminal contactor in the spark plug and secure the elbow by first tightening the elbow to the spark plug and secondly the coupling nut to the conduit.

SPARK PLUG CONDUITS REMOVAL—Remove the shielded terminal contactors from the cable and remove the elbow from the conduit. Loosen the coupling nut attaching the spark plug conduit to the manifold ring and slide the conduit and cylindrical rubber grommet off the ignition cable.

INSTALLATION—Slip a cylindrical rubber grommet over the ignition cable with one end of the grommet seating

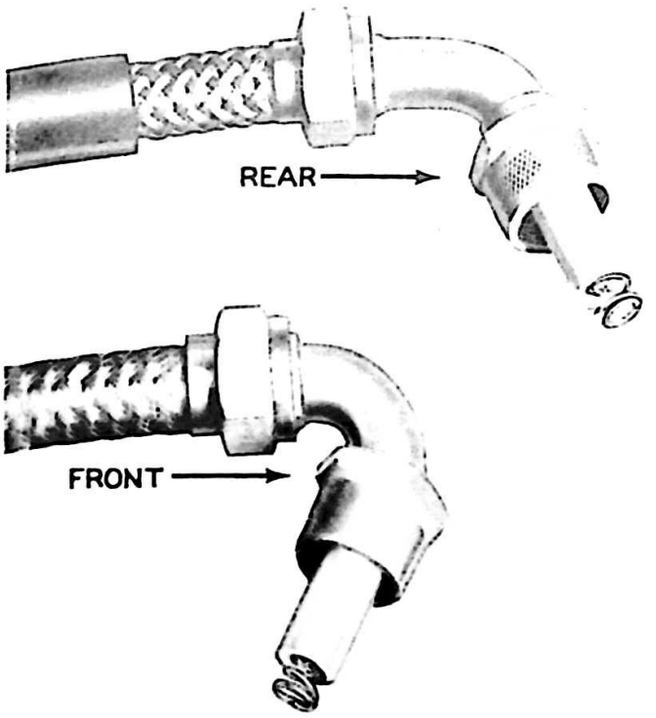


Figure 53—Spark Plug Elbow Angles

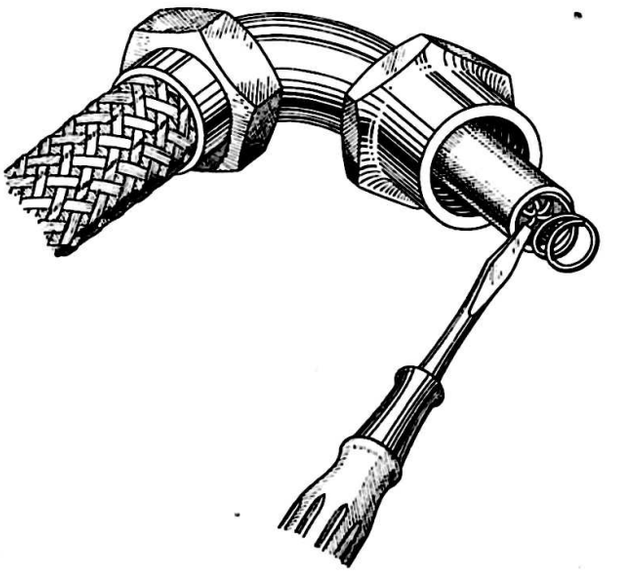


Figure 54—Fanning Wire Strands over Contactor Washer

in the manifold ring. Slide the shielded conduit over the spark plug end of the ignition cable. Tighten the coupling nut at the manifold ring.

Install the metal-and-rubber grommet and elbow on the spark plug end of the conduit but leave it loose. Install the terminal contactor on the end of the cable. Insert the terminal contactor in the spark plug well. Secure the elbow to the spark plug. Then tighten the coupling nut which holds the elbow to the conduit but be certain that the conduit is unstressed.

IGNITION CABLE HARNESS

REMOVAL — Detach the elbows from the spark plugs and withdraw rear spark plug conduits from the cylinder head air deflectors. Detach the spark plug conduit clips from the push rod housings.

Remove intake pipes No. 1 and 9. Remove the intercylinder air deflectors between cylinders No. 1 and 2 and No. 1 and 9.

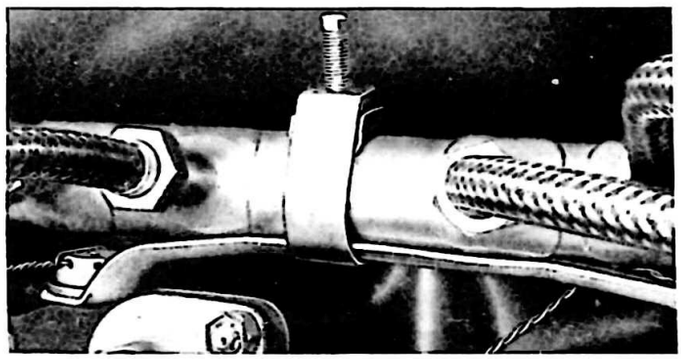


Figure 55—Ignition Harness Clamped to Bracket

Remove the clamps securing the manifold ring to the brackets on the crankcase front section. See figure 55. Remove the clamp assembly securing each magneto conduit to its crankcase bracket. Loosen all joints and couplings which will facilitate removal.

Remove the distributor blocks from the magnetos and remove the ignition cables from the blocks. Release the cables from the ignition harness cross-over.

Remove the ignition cable harness from the engine, pulling it forward.

INSTALLATION—Place the ignition cable harness in position on the engine, passing the magneto conduits between cylinders No. 1 and 2 and No. 1 and 9.

Install the clamps securing the manifold ring to the brackets attached to the flange of the crankcase front section. Install the clamp assembly securing each magneto conduit to the crankcase. See figure 56. In addition, install the locking clamps to secure the knurled or slotted magneto conduit nuts.

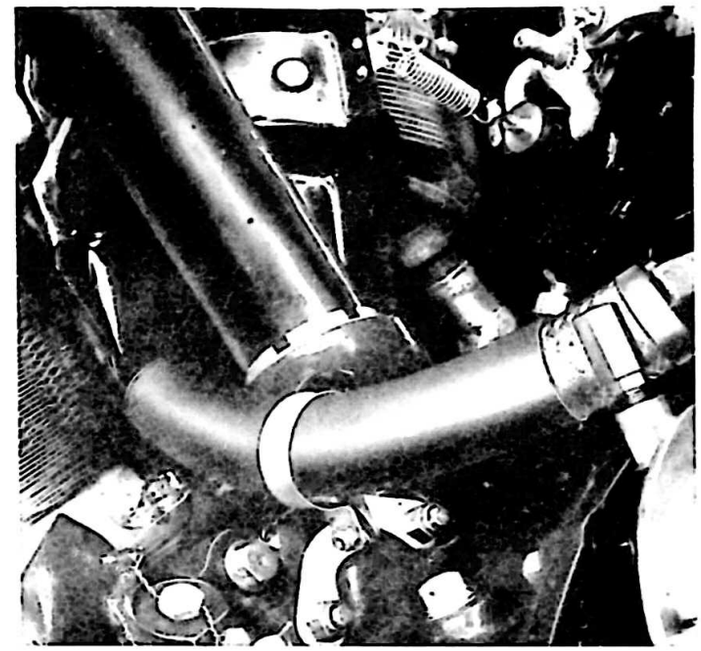


Figure 56—Magneto Conduit Bracketed to Crankcase

If a new harness is being installed, it will be necessary to pass the cables through the magneto outlet flange. With a reinstallation or replacement of the harness it will then be necessary to route certain cables through the radio-shielded ignition harness cross-over. Direct the cables to their proper distributor blocks as follows:

Pass the rear spark plug cables from cylinders No. 2, 3, 4, and 5 from the right magneto conduit through the cross-over to the left magneto. The front spark plug cables from cylinders No. 1, 2, 3, 4, and 5 pass directly to the right magneto. Pass the front spark plug cables from cylinders No. 6, 7, 8, and 9 from the left magneto conduit through the cross-over to the right magneto. The rear spark plug cables from cylinders No. 6, 7, 8, 9, and 1, pass directly to the left magneto. Refer to the ignition wiring diagram. See figures 57 and 58. Insert the cables from the cross-over and the cables from the outlet flange through their respective ports in the distributor block radio shield. Secure the outlet flange to the radio shield with two cap screws lockwired.

Insert the cables in the distributor block wells and install the distributor blocks in the magnetos following the applicable directions on pages 70 and 71.

Reinstall the intercylinder air deflectors and the intake pipes that were removed.

Connect the spark plug terminals to the spark plugs

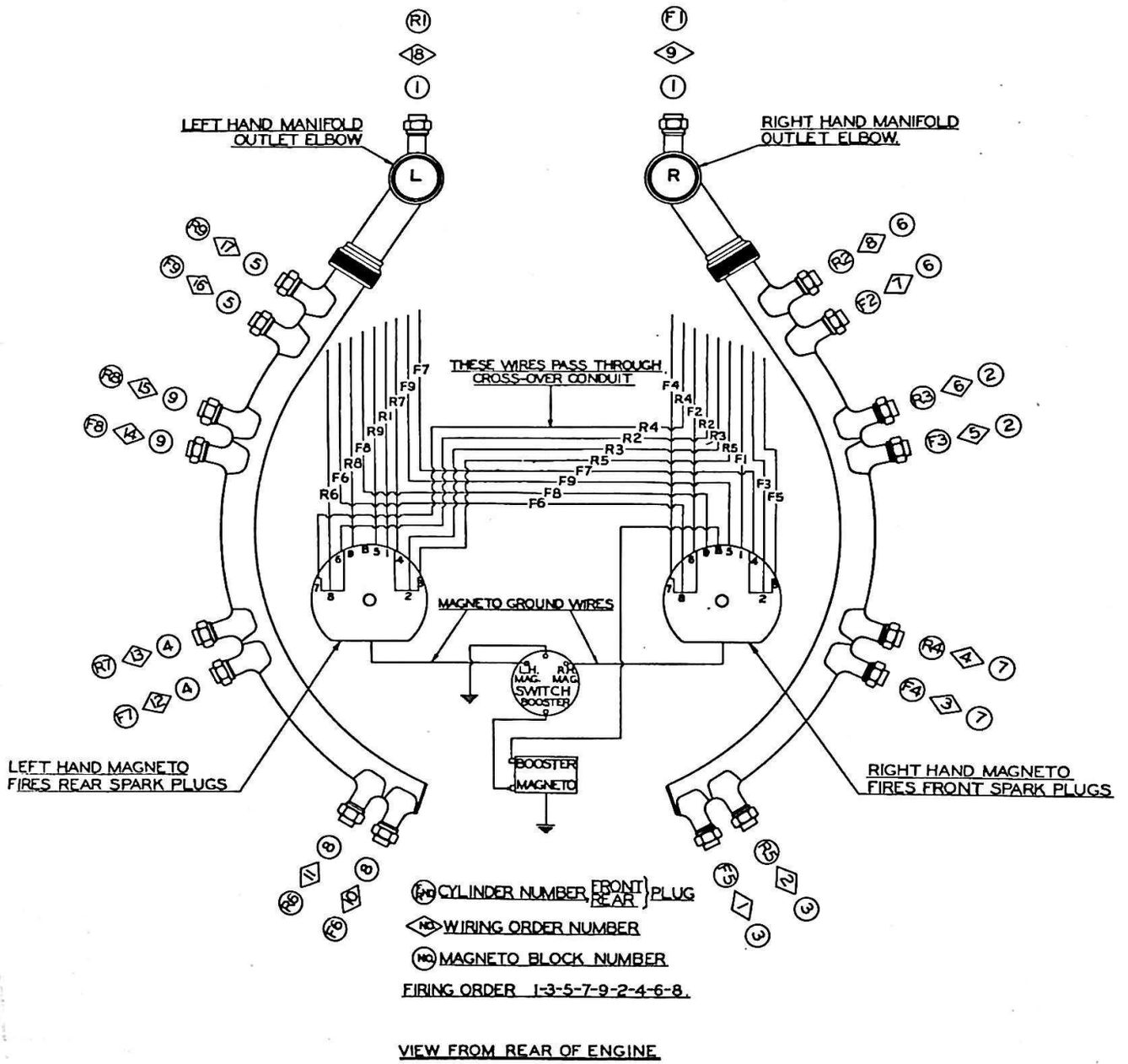

LEFT HAND MANIFOLD OUTLET ELBOW
RIGHT HAND MANIFOLD OUTLET ELBOW
THESE WIRES PASS THROUGH CROSS-OVER CONDUIT
MAGNETO GROUND WIRES
LH. MAG. RH. MAG. SWITCH BOOSTER
BOOSTER MAGNETO
LEFT HAND MAGNETO FIRES REAR SPARK PLUGS
RIGHT HAND MAGNETO FIRES FRONT SPARK PLUGS
CYLINDER NUMBER, FRONT / REAR PLUG
WIRING ORDER NUMBER
MAGNETO BLOCK NUMBER
FIRING ORDER 1-3-5-7-9-2-4-6-8.
VIEW FROM REAR OF ENGINE

Figure 57—Ignition Wiring Diagram (Split Type)

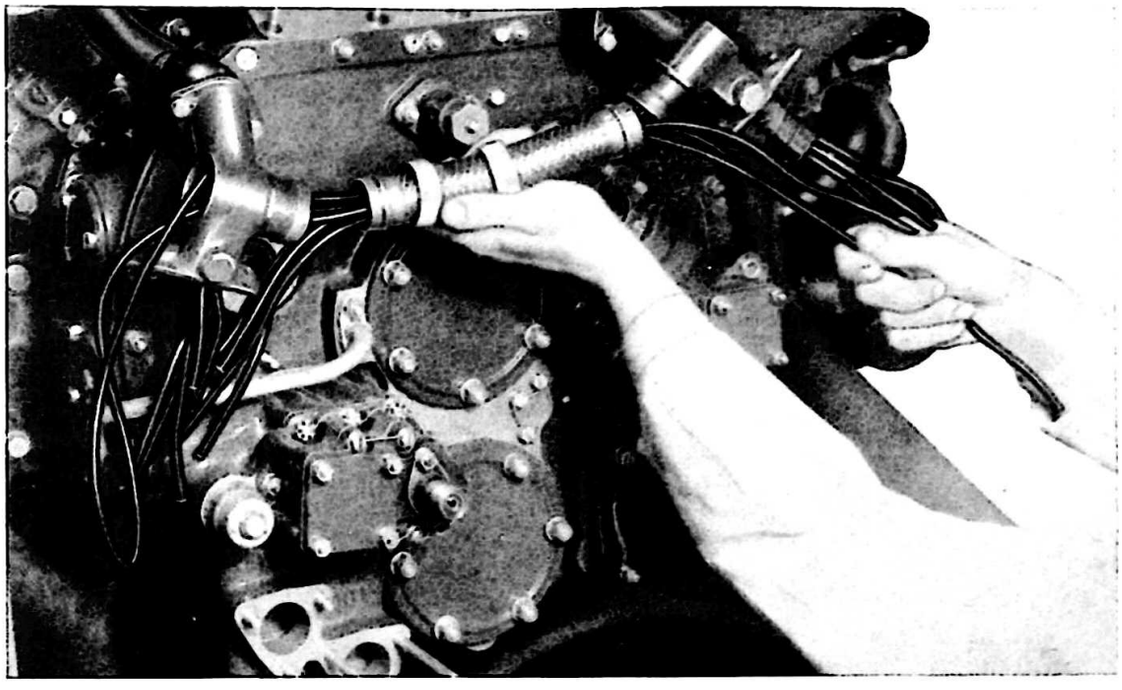


Figure 58—Directing Cables Through Ignition Harness Cross-over

and attach the spark plug conduit clips to the push rod housings.

Tighten all couplings in the ignition cable harness assembly including the locking clamps.

Instructions for the installation and removal of the continuous type manifold ring are the same as above with the exception of all reference to the cross-over bar which does not exist in the continuous type manifold ring.

NOTE: Sealing compound should be applied during the above procedures following the instructions under that heading on page 76.

IGNITION CABLES REMOVAL—If necessary to replace one or more ignition cables between overhaul periods, the operation can be performed without removing the ignition harness.

Detach the terminal contactor from the spark plug, remove the terminal elbow, and withdraw the spark plug conduit.

Detach all clamps or clips and loosen all connections in the harness and magneto outlet assemblies that will facilitate replacement of the cable.

Remove the distributor block from the magneto and withdraw the subject cable from its well in the block.

INSTALLATION—Strip the insulation from the magneto end of the cable to be replaced so that approximately 1 inch (25 millimeters) of wire is exposed. Strip the same length of insulation from the replacement cable. Tie together the two ends of wire in a neat square knot. If a seven-millimeter cable is being installed—or if the clearances in the harness are close—coat the cable with a light film of Dow Corning No. 4 compound. Powdered talc may be used to facilitate the entry of lacquered cables only.

Draw the new cable into the harness by pulling on the spark plug end of the old cable. It is advisable for two men to work together, one pulling slowly on the old cable and the other feeding the new cable into the harness assembly. Refer to the ignition wiring diagram for the travel of the cable through the ignition harness cross-over or directly into the magneto conduit. See figures 57 and 58.

When the new cable has been drawn through the manifold far enough for contact with the spark plug, cut the old cable from the new. Install the spark plug conduit with new rubber grommet; spark plug elbow with new metal-and-rubber grommet, but do not tighten, and a new terminal contactor. Secure the terminal contactor to the spark plug, then tighten the elbow to the conduit coupling nut taking care to leave the conduit unstressed.

Cut the cable at the magneto end the correct length to enter the distributor block. Select a washer stamped with the proper distributor block well number. Strip sufficient insulation from the magneto end of the cable and insert the wire strands through the hole in the center of the washer. Separate the strands and bend them back

through the slots at the sides of the washer. Secure the strands between the washer and the cable insulation with pliers, Tool No. 804448. Tag the cable with its distributor block well number.

Insert and secure the cable in the distributor block. Reinstall the distributor block in the magneto.

Attach all clamps or clips that were removed. Tighten all couplings in the ignition harness assembly as well as locking clamps.

Instructions for the removal and installation of ignition cables when a continuous type manifold ring is employed are the same as outlined above with the exception of all reference to the cross-over bar which does not exist in this arrangement.

SEALING COMPOUND It is recommended that a sealing compound, Dow Corning No. 4 compound, be injected to fill the air space around the ignition cable in the spark plug wells, spark plug elbows and terminal contactors, as well as magneto distributor block wells. Carefully clean all the wells and the exposed ends of the ignition cables. When injecting the sealing compound, use the compound gun assembly, Tool No. 803829; or gun assembly, Tool No. 803774, provided in some engine tool kits. For detailed information, refer to the manufacturer's instructions contained in the carton with the cartridges of the compound.

SPARK PLUG ELBOWS—Slip the metal-and-rubber grommet and the spark plug elbow over the end of the ignition cable. Do not tighten the coupling nut at this time. Inject compound into the elbow until it begins to run out around the edge of the coupling nut. Wipe off excess compound with a clean lintless cloth. Seat the grommet and tighten the coupling nut slightly. Final tightening occurs later. Inject compound into the terminal contactor, applying one-half turn to the handle of the gun. Install the terminal contactor on the end of the ignition cable.

SPARK PLUG WELLS—Inject sealing compound to fill the spark plug well. Loosely install the terminal contactor and elbow, seating the elbow flange on the spark plug barrel to force out any excess compound. Remove excess compound with a clean lintless cloth and secure the elbow to the spark plug by tightening the coupling nut.

DISTRIBUTOR BLOCK WELLS—Insert end of gun into a cable well and inject compound by giving handle of gun one-half turn. Coat at least 3 inches (75 millimeters) of the ignition cable end with a film of the compound not less than $\frac{1}{32}$ inch (.79 millimeter) thick. Insert cable in distributor block until it bottoms in its well. Holding the cable in position, wipe off any excess compound at the piercing screw hole. Great care must be taken that no compound remains on the block electrodes. Insert and tighten the piercing screw.

PRIMING SYSTEM REMOVAL—If it is necessary to remove the two-point priming system used on these engines, employ the following procedure: Loosen the coupling nuts on the priming tube assembly. Remove the clamps securing the priming tubes to the carburetor. Remove the priming lines. Unscrew the nipples from the carburetor adapter and the tee joining the right and left hand tubes. Detach the tee from its connection to the primer solenoid.

INSTALLATION—Insert the primer tube tee at the priming solenoid connection. Screw in the nipples in either side of the carburetor adapter. Install the left and right priming tubes and tighten all the coupling nuts. Install the clamps on the priming tubes and secure them to the carburetor.

CARBURETOR REMOVAL — For maintenance, servicing, and repair of the Bendix-Stromberg injection carburetor, refer to the manufacturer's instructions. For removal of the carburetor from the engine proceed as follows: Shut off fuel supply from fuel pump to carburetor. Disconnect the throttle and mixture controls and remove all lines to connections in the carburetor and adapter. Remove all lines and heater controls from the airscoop. Remove the palnuts, nuts, and plain washers securing the airscoop to the carburetor. Remove the airscoop, gasket, air inlet screen, and gasket.

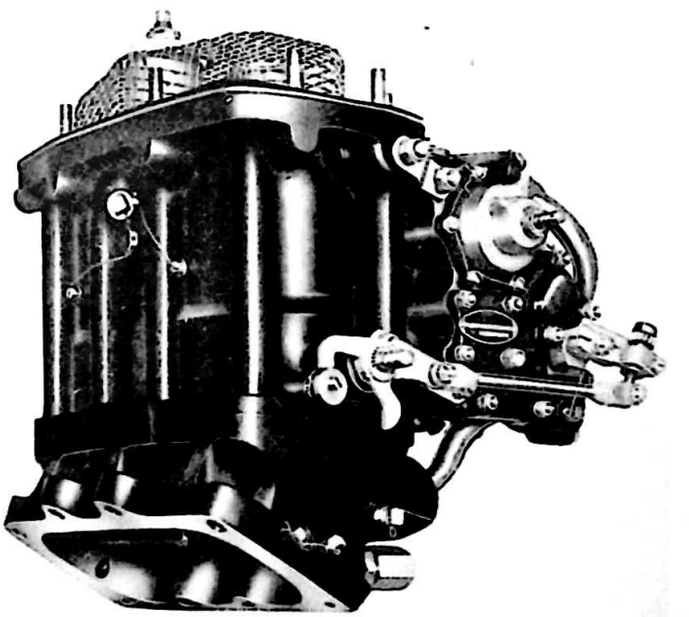


Figure 59—Carburetor—Showing Mounting Flange

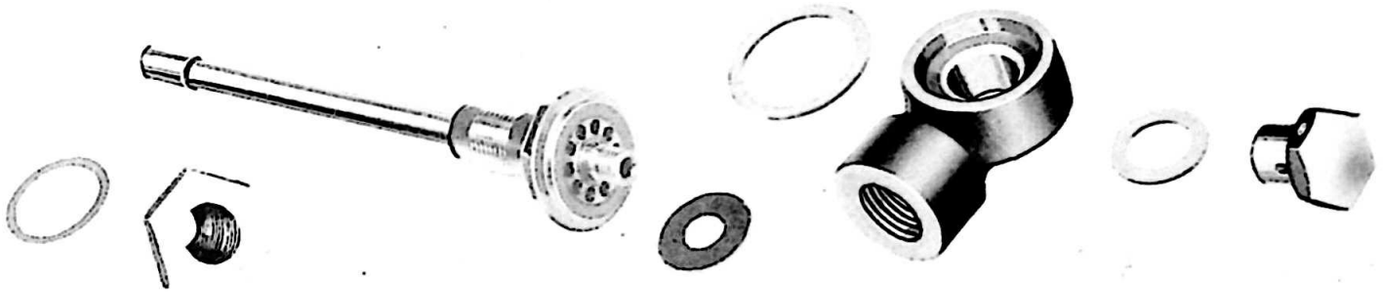


Figure 60—Supercharger Drain Valve

Remove the elastic stop nuts and spherical seat washers securing the carburetor to the supercharger rear housing. See figure 59. Remove the carburetor and gasket. Cover the induction passage with a suitable plate drilled to pass over the carburetor adapter attaching studs.

INSTALLATION—Drain and slush the carburetor before installation. Remove the cover plate from the mounting pad on the supercharger rear housing. Place the carburetor and gasket in position over the mounting studs and install the spherical seat washers. Secure the assembly with elastic stop nuts.

Connect all lines and controls disconnected for removal of the carburetor. Check all controls for full travel at the carburetor.

Place a gasket over the airscoop mounting studs and install the screen. Install a gasket between the screen and scoop and install the airscoop. Secure the airscoop and air inlet screen with washers, nuts, and palnuts.

SUPERCHARGER DRAIN VALVE (STANDARD TYPE) REMOVAL—Disconnect the drain line from the outlet connection of the supercharger drain valve. Remove the drain valve assembly by unscrewing the drain valve body out of its shouldered bushing in the supercharger rear housing, using wrench, Tool No. 800821.

The drain valve assembly may be separated into its component parts by breaking the lock wire and unscrewing the steel plug from the outer end of the unit. The aluminum alloy housing may be removed, followed by the drain valve disk, gasket, drain valve body, and tube. The drain tube is pressed into the steel body and should not be removed. See figure 60.

INSTALLATION—Place a gasket on the drain valve housing and place the drain valve disk over the outer threaded end of the drain body. Install the drain valve body with tube in the supercharger drain valve housing. Insert the plug with washer through the drilled housing and screw into the threaded end of the steel body. The plug should not be tightened until the drain valve has been installed in the engine.

Insert the drain tube into its hole in the lower right side of the supercharger rear housing by screwing the drain valve body into the shouldered bushing. Properly position the drain valve housing for attaching the drain line. Secure it by tightening and lockwiring the drain valve retaining plug.

Connect the drain line to the outlet nipple in the aluminum alloy drain valve housing. The end of the drain tube must face into the slip stream.

SUPERCHARGER DRAIN VALVE (TURBO TYPE) REMOVAL — Disconnect the drain line from the outlet connection. Break the lock wire securing the valve housing and unscrew the valve housing from the valve body. Be careful not to drop the piston and disk unit which may remain with either the valve body or in the valve housing. Remove the piston and disk unit. Unscrew the valve body, using wrench, Tool No. 800821 from the supe charger rear housing and withdraw the body and tube assembly unit. See figure 61.

INSTALLATION—Install two new rubber packing rings in the groove at the small end of the valve body. Install the valve body using a washer between the flange on the valve body and the supercharger rear housing. Install a new rubber packing below the flange at the large end of

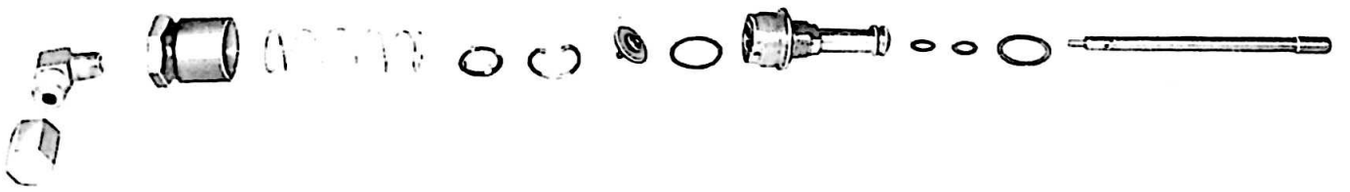


Figure 61—Turbosupercharger Drain Valve

the body. Place the piston and disk into the housing and install the tube. Assemble the housing to the valve body.

Lockwire the drain valve housing to the supercharger rear housing, and install the drain line in the valve housing outlet.

BREATHER FLANGE REMOVAL—Detach the breather elbow; or remove the substituting plug. Remove the two elastic stop nuts and washers and remove the breather flange, gasket, screen, and gasket from the two attaching studs at the top of the supercharger front housing.

INSTALLATION—Install gasket, screen, gasket, and breather flange on the two attaching studs at the breather vent location. Secure with elastic stop nuts and washers. Install the elbow in the vent at the top of the flange; or install the substituting plug.

AIR-MAZE OIL SEPARATOR REMOVAL—Remove the four cap screws and remove the cover and gasket. Lift out the screen. Remove the two special nuts and washers from the bottom of the housing. The housing and gasket may then be withdrawn from the two attaching studs at the top of the supercharger front housing. See figure 62.

INSTALLATION—Place a gasket and the housing over the two attaching studs at the breather vent location. Install washers and the two special nuts over the same two studs which project through the bottom of the housing. Lockwire the nuts together. Install the screen in the housing. Install the cover, with gasket, and secure to the housing with four cap screws and washers. Lockwire the cap screws in pairs.

EXTERNAL OIL SCAVENGE LINE REMOVAL—Remove the three elastic stop nuts securing the external oil scavenge line to the oil sump.

Loosen the two hose connection clamps which secure the external oil scavenge line to the oil pump. Slide the clamps back over the scavenge line and remove the external oil scavenge line.

Remove the hose connection from the oil pump; remove the gasket attached to the oil sump outer flange.

Cover both external oil scavenge line connection holes.

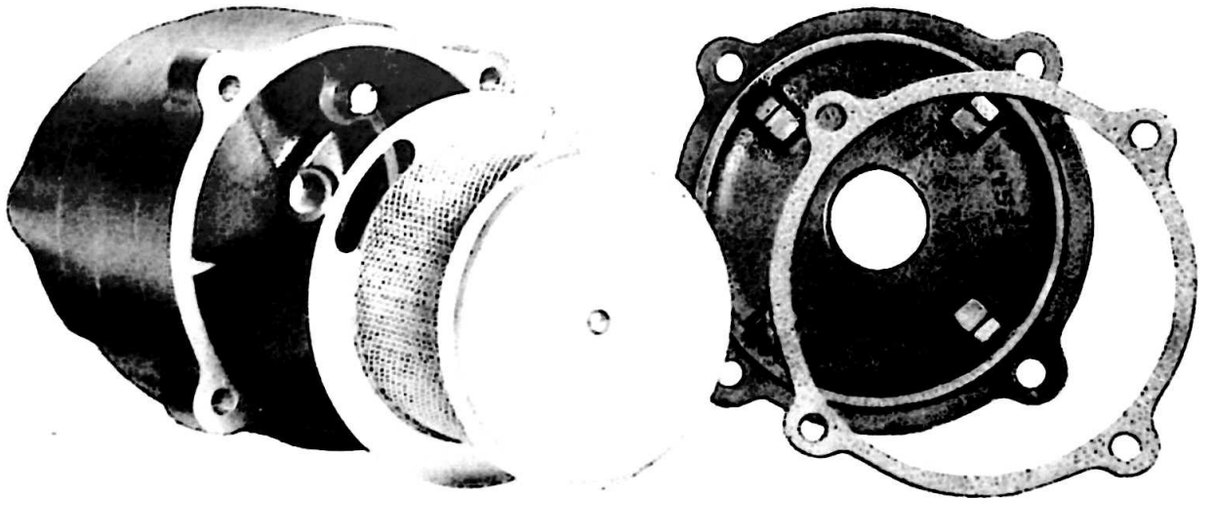


Figure 62—Air-Maze Oil Separator

INSTALLATION—Remove covers on the connection holes. Install a new hose connection to the oil pump. Insert a gasket and attach the external oil scavenge line on the oil sump outlet flange. Secure assembly with three elastic stop nuts.

Locate the two hose connection clamps on the hose at the oil pump connection and secure the external oil scavenge line to the oil pump. Ensure that all connections are tight. See figure 63.

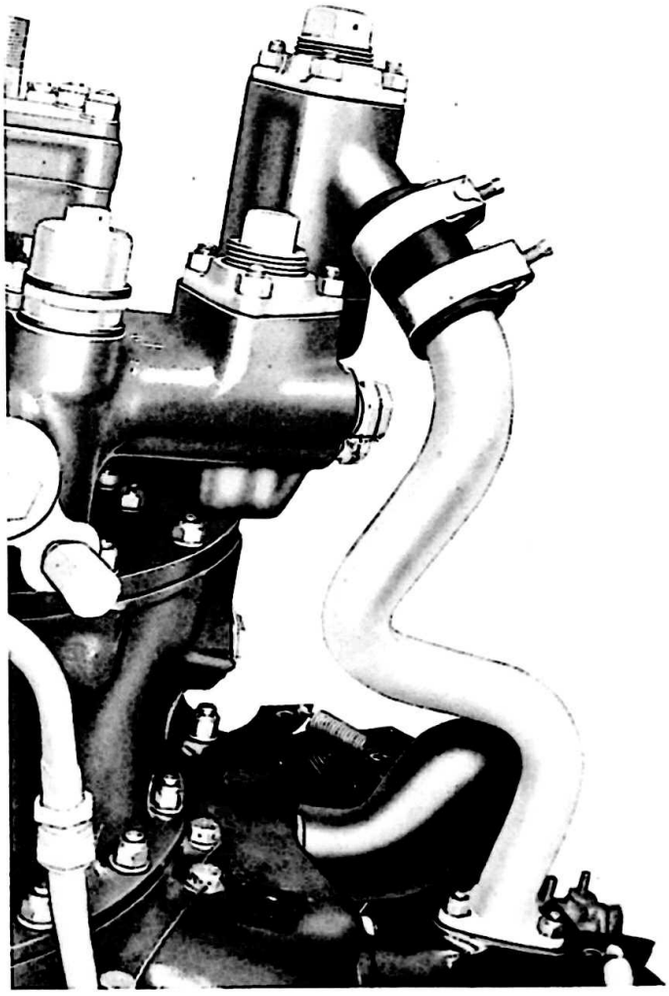


Figure 63—External Oil Scavenge Line

OIL SUMP REMOVAL—Remove intake pipe No. 5 and the intercylinder air deflector between cylinders No. 5 and 6. Remove the adjacent rocker box covers of cylinders No. 5 and 6 and exhaust push rod housing and push rod of cylinder No. 6. Remove the external oil scavenge line; or loosen the connection at the oil pump. Remove the magnetic sump plug and strainer from the

Figure 64—Removing Magnetic Sump Plug

Figure 65—Magnetic Sump Plug Ferrous Particles

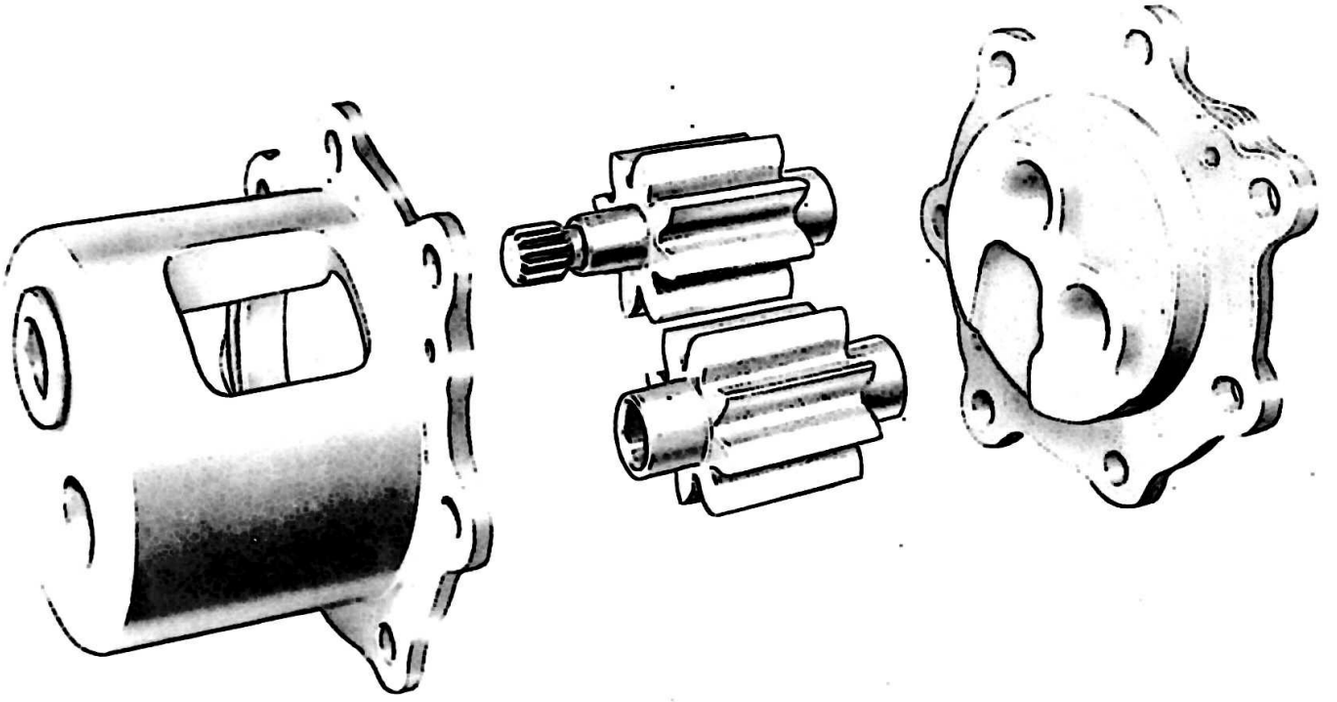


Figure 66—Oil Sump Pump Housing and Gears

sump. See figure 64. Drain the oil into a clean receptacle. Inspect the magnetic plug and strainer for dirt or metal particles and then wash them in unleaded gasoline. See figure 65. Loosely reinstall the plug.

Remove the three elastic stop nuts and washers securing the front attaching flange to the crankcase front section. Support the sump and remove the two elastic stop nuts and washers from each arm of the sump. Withdraw the sump.

NOTE: The sump pump drive shaft will slide out when removing the sump. Use extreme caution to prevent this shaft from falling.

To remove the oil sump scavenge pump, remove the seven elastic stop nuts and washers. Tap the pump body lightly with a fiber mallet and remove the pump body and gasket from the sump housing. Separate the cover from the pump housing and remove gasket and both pump gears. See figure 66.

INSTALLATION—Place gaskets on the mounting flange locations and install the oil sump on the engine. Secure the attaching flange of the sump to the crankcase front section with three elastic stop nuts and washers. Secure each arm of the sump to attaching studs on the supercharger front housing with two elastic stop nuts and washers.

Insert the sump pump drive shaft into the sump, meshing the splines at the upper end of the shaft with splines on the inside of the coupling gear.

Place a gasket and the sump pump body in its recess in the oil sump. Position the outer end of the sump pump drive shaft on the body during this installation.

Insert the drive shaft gear in its housing, splining it into the outer end of the sump pump drive shaft. Install the pressure idler gear in the body. Install gasket and cover and secure the assembly with seven elastic stop nuts and washers.

Install the oil screen strainer and magnetic sump plug, with copper asbestos gasket, in the oil sump. See figure 67. Lockwire the magnetic sump plug.

Reinstall the rocker box covers, interclylinder air deflector, intake pipe, push rod, and push rod housing that were removed. Reinstall the external oil scavenge line.

OIL PUMP PRESSURE RELIEF VALVE

ADJUSTMENT—Break the lock wire and remove the valve cap and gasket. Loosen the lock nut which prevents movement of the slotted adjusting screw. Use wrench, Tool No. 801999. To increase the relief valve spring tension and engine oil pressure, turn the screw in a clockwise direction. See figure 68. When the

desired engine oil pressure has been obtained, tighten the lock nut against its shouldered lead-plated washer. Reinstall the valve cap and its shouldered lead-plated washer.

REMOVAL—Remove the oil pressure relief valve cap and lock nut with their shouldered lead-plated washers.

Unscrew the slotted adjusting screw all the way off the bronze relief valve body. Remove the coiled spring and withdraw the steel piston from the bore of the bronze relief valve body.

Unscrew the relief valve body from the oil pump by inserting the two-lug wrench, Tool No. 83660, into the slots of the body.

INSTALLATION—Screw the relief valve body into the oil pump and tighten securely. Insert the piston-type valve into the bronze relief valve body, placing the coil spring inside the piston.

Screw the adjusting screw approximately one-third of its length on the outside diameter of the bronze body and install the lock nut and its shouldered lead-plated washer loosely on the adjusting screw. Reset the adjusting screw to give the desired engine oil pressure. Tighten the lock nut.

Install the valve cap and its shouldered lead-plated washer and lockwire the cap securely.

NOTE: Both shouldered lead-plated washers should be installed with the shoulder facing rear.

OIL PUMP INLET CHECK VALVE

REMOVAL—Break the lock wire and remove the plug retainer from the left side of the oil pump. Remove the copper asbestos gasket, spring, and hollow piston from the bore of the bronze valve body. The bronze valve body is pressed into the oil pump body thus prohibiting removal in the field.

INSTALLATION—The steel piston employs one piston ring which may be replaced without the use of special tools. Expand the ring slightly and slide it over the chamfered end of the piston dome and into the piston ring groove. Insert the piston ring into the bronze check valve body, compressing the ring to permit entrance. Place the coiled spring into the hollow piston. Place a gasket under the head of the retainer and screw on the retainer. Lockwire the retainer.

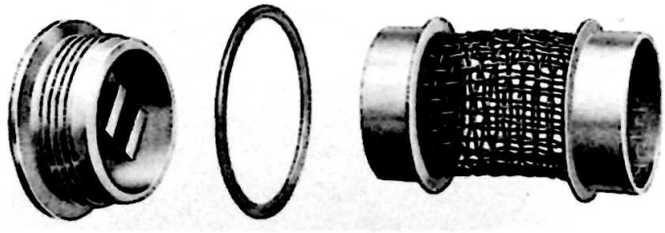


Figure 67—Magnetic Sump Plug and Screen Assembly

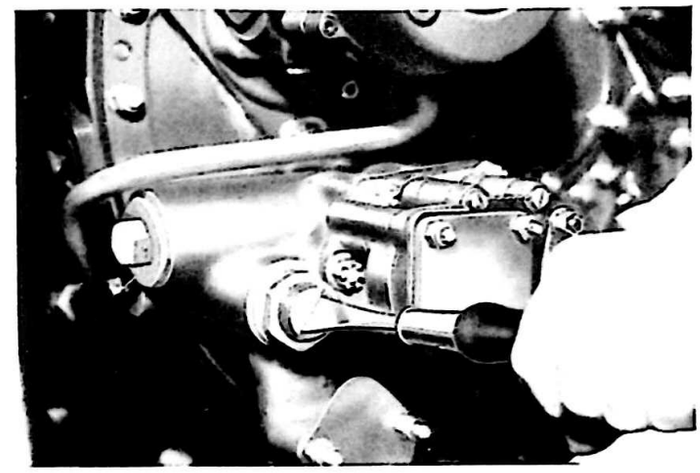


Figure 68—Oil Pump Pressure Relief Valve Adjustment

If a check valve is not used in the installation, a substituting plug is used in its place. This plug is a drive fit into the bronze valve body.

OIL PUMP AND TACHOMETER DRIVE HOUSING

REMOVAL—Unscrew the temperature bulbs from the inlet and outlet chambers of the oil pump. Detach the oil inlet and outlet lines, also the tachometer connections. Remove the oil pump attaching nut from the attaching leg at the right of the oil pump. Use wrench, Tool No. 800684. Remove the five slotted cap screws and remove the tachometer drives housing, cover, and gasket as a unit. See figure 69. Remove the slotted nuts and washers from the eight oil pump attaching studs placed around the oil pump rear cover.

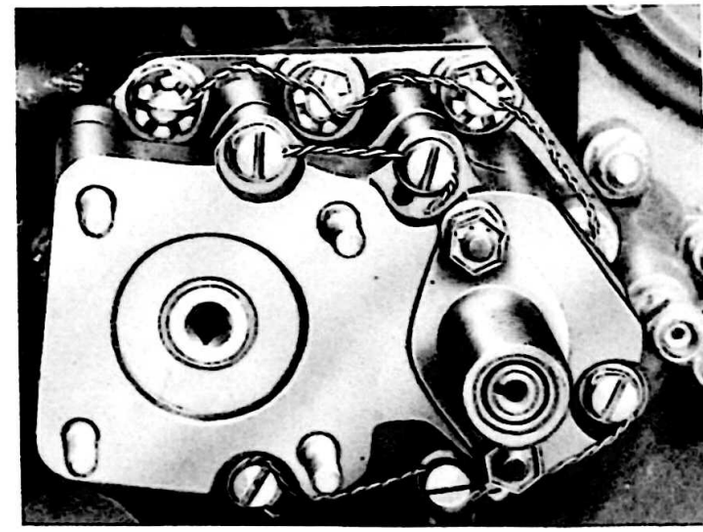


Figure 69—Tachometer Drives on Oil Pump

Withdraw the entire oil pump assembly to the rear and remove the gasket. The oil pump parts may be temporarily retained together by bolts placed through two of the long stud holes.

INSTALLATION—Place a gasket over the pump attaching studs on the supercharger rear housing cover. Coat the oil pump drive shaft with petrolatum. Install the pump over the attaching studs, meshing the coupling with the splined end of the drive shaft in the supercharger rear housing cover as the pump body settles into place. Install the plain washers and slotted nuts on the attaching studs. Tighten to the correct torque value and lockwire. Install a gasket and the tachometer housing assembly as a unit. Secure with five slotted cap screws and lockwire. Place a plain washer under the head of the oil pump attaching nut which secures the attaching leg of the oil pump to the supercharger rear housing cover and lockwire.

Reinstall the tachometer connections, oil lines, and temperature bulbs.

OIL STRAINER REMOVAL—Remove the three special nuts and washers securing the oil strainer to the supercharger rear housing studs. After removal, wash the strainer in unleaded gasoline. See figure 70.

INSTALLATION—Place a gasket over the attaching studs on the mounting pad. Place a new packing ring in the rear cover groove. Insert the strainer with its inner end fitting in the supporting boss under the center of the supercharger rear housing cover. Secure the strainer to its three attaching studs with washers and special nuts lockwired. See figure 71.

EXTERNAL HYDRO-OIL LINE REMOVAL — Loosen the coupling nut connecting the two segments of tubing. Loosen the coupling nut securing the front tube to the elbow in the crankcase front section. Detach the rear tube clamp from the rear bracket. Remove the elastic stop nuts which secure the flange over the studs in the rear cover. Withdraw the rear oil tube and remove the gasket under the flange.

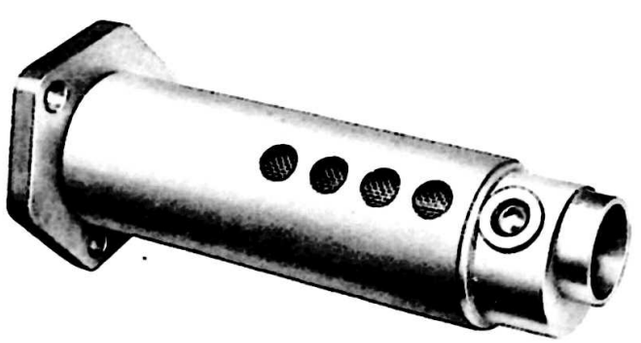


Figure 70—Oil Screen Strainer

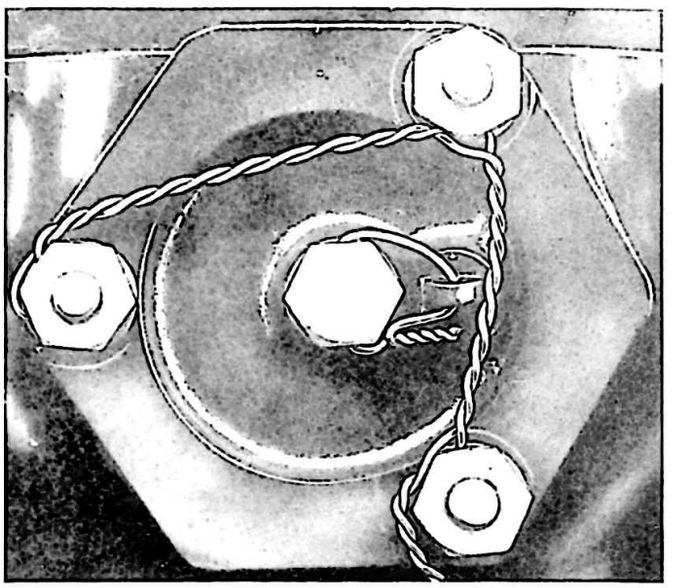


Figure 71—Oil Screen Strainer Lockwired

Detach the front tube clamp from the bracket and withdraw the front tube.

INSTALLATION—Assemble the clamp on the front tube assembly. Insert the front end of the tube from the rear of the engine under intake pipe No. 7 and under intercylinder air deflector between cylinders No. 7 and 8. Screw the front connection nut onto the elbow installed on the crankcase front section. Do not tighten at this time. Attach the front tube clamp to the bracket on the supercharger rear housing.

Assemble the clamp on the rear tube. Place a gasket over the two studs and install the rear oil tube on the rear cover. Secure the rear clamp to the bracket on the supercharger rear housing cover. See figure 72. Secure the flange to the two studs with elastic stop nuts. See figure 73.

Secure the two segments of tubing by tightening the coupling nut. Tighten both front and rear tube clamps and all connections.

TWO-SPEED SUPERCHARGER CLUTCH CONTROL VALVE REMOVAL—The two-speed supercharger clutch control valve is located in the raised portion of the supercharger rear housing cover at the immediate right of the oil pump between the starter and generator. For accessibility in replacing this unit on an engine, it may be necessary to

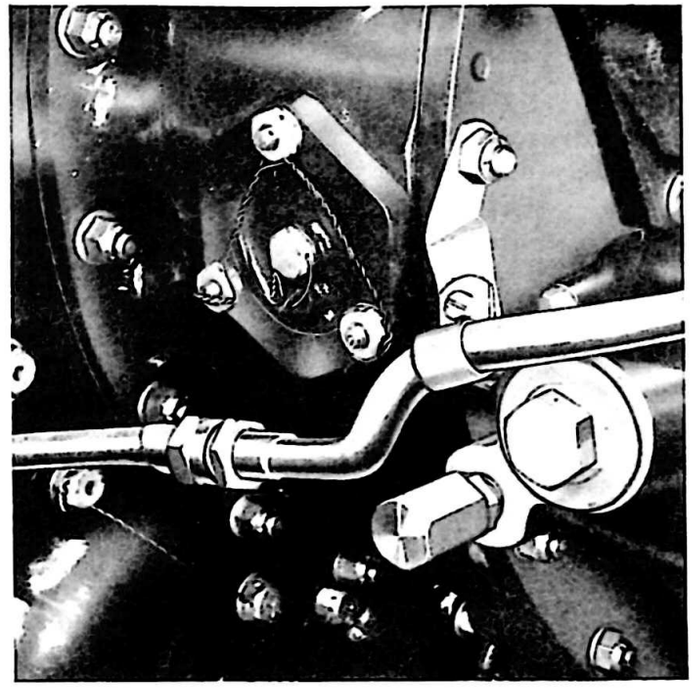


Figure 72—Hydro-Oil Line Rear Support Bracket

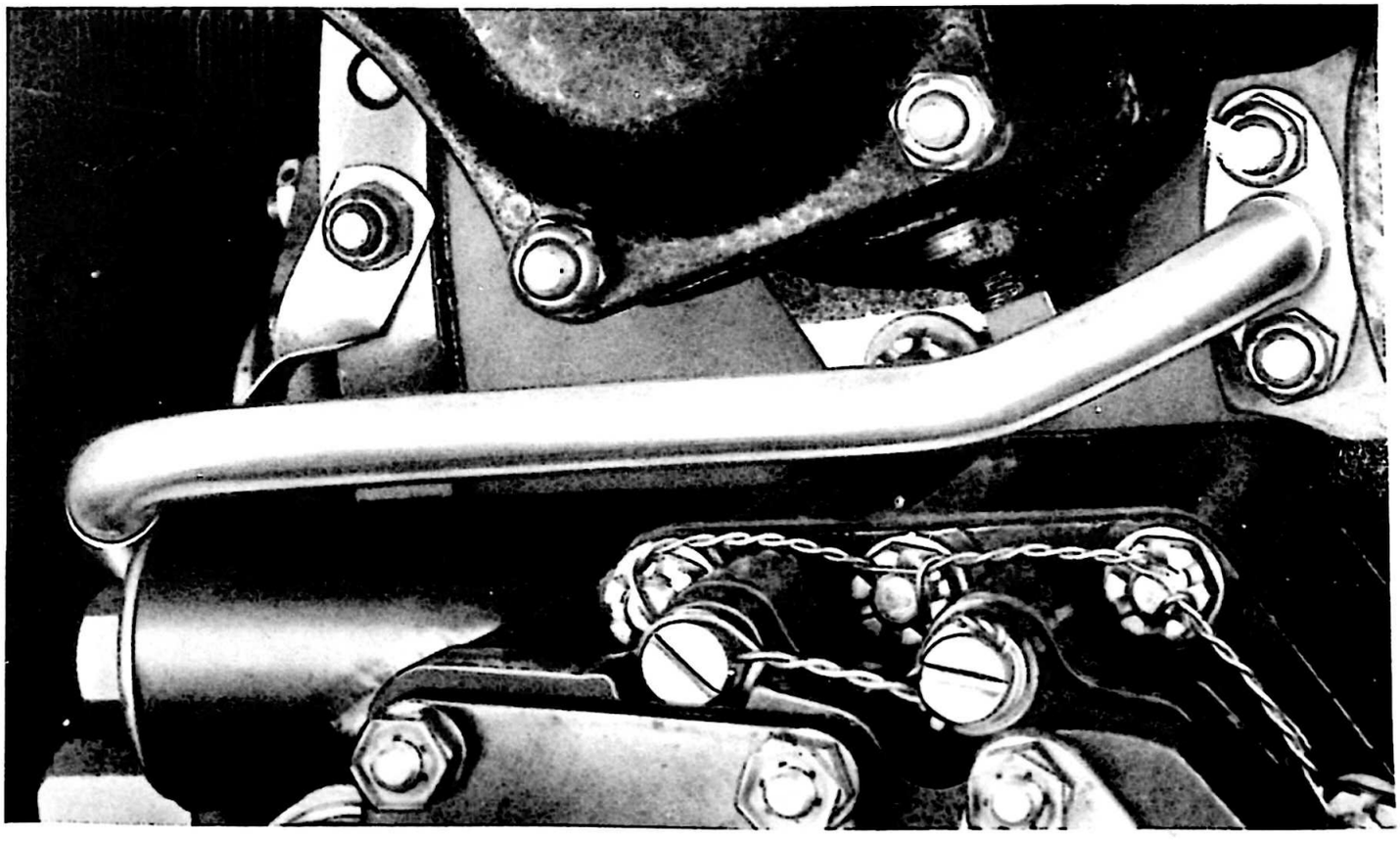


Figure 73—Hydro-Oil Line Rear Connection

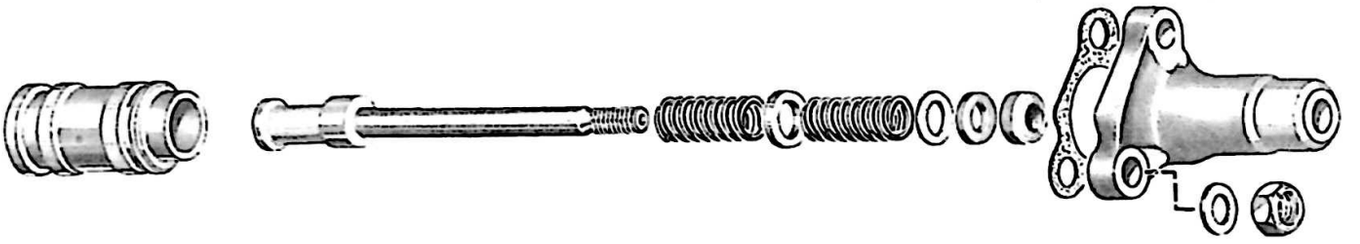


Figure 74—Two-Speed Clutch Control Valve

remove the starter, generator, or oil pump (whichever may be removed more conveniently).

Disconnect the push-pull control from the end of the piston type selector valve and temporarily install a spacer and nut on the threaded end of the valve shaft. Remove the elastic stop nuts and washers from the three valve housing attaching studs. Withdraw the housing with the valve assembly.

Remove the nut and spacer on the threaded end of the valve stem and remove the valve and spring assembly from the housing. Discard the packing rings.

INSTALLATION—Place a valve spring, washer, another valve spring, another washer, rubber packing ring, and cork packing ring on the valve stem. See figure 74. Lubricate and install the valve assembly in the control valve housing. Push the valve in against the spring tension and install a spacer and nut on the threaded end of the valve stem. Tighten the nut against the spring tension until the valve is in high speed ratio or retracted position.

Place a gasket on the supercharger rear housing cover, install the control valve assembly, and secure it with three washers and elastic stop nuts. Remove the nut and spacer from the valve stem. Check the operation of the valve for full travel and freedom from binding.

Connect the push-pull control to the connection on the threaded end of the piston-type selector valve.

FUEL PUMP DRIVE SHAFT AND OIL SEAL

REMOVAL — With the fuel pump removed from its mounting pad, insert the two puller screws, Tool No. 84956, and remove the fuel pump drive shaft and support assembly as one unit.

Insert a small diameter fiber drift in the outer end of the support and drive out the fuel pump drive shaft from its supporting bushings.

Removal of the fuel pump drive shaft oil seal assembly is effected by withdrawing the seal assembly from the fuel pump drive support. Use puller, Tool No. 801534. This assembly consists of a steel ring, in which a synthetic seal is assembled reinforced by a steel spring. This assembly is replaced as one unit and cannot be disassembled.

INSTALLATION—Replace the fuel pump drive shaft oil seal assembly as one unit in the drive shaft support. Install the seal with the synthetic lip facing inward, pressing the seal from the outer end until the spring bottoms in the support. Use installing tool, Tool No. 801225.

Insert the fuel pump drive shaft into the support with the gear end of the shaft toward the inner end of the support. Tap the gear into place until the shoulder on the inner end seats against the flange of the rear supporting bushing. Use extreme caution in inserting the shaft through the seal. Use a gasket under the flange of the support and insert the support and drive shaft assembly into the supercharger rear housing. Rock the assembly slightly to insure proper meshing of the gears.

Install the fuel pump or its substituting cover with gasket.

DUAL ACCESSORY DRIVES

REMOVAL—When removing an accessory on the dual accessory drive housing, refer to the manufacturer's instructions for specific information pertaining to that accessory. Remove all lines from the accessory driven by that unit and proceed as follows:

Remove the elastic stop nuts and washers from the four attaching studs on each of the two mounting pads and withdraw the accessories or substituting covers and their gaskets. Break the lock wire and remove the special cap nuts and washers from the two studs extending from the supercharger rear housing cover through the upper left side of the dual accessory drive housing and cover. Remove the elastic stop nut and washer from the one remaining attaching stud on the right side of the cover adjacent to the lower drive mounting pad. Remove the dual accessory drive housing cover and gasket. Be particularly careful not to allow the spur gears to drop out of their bushings in the housing. Withdraw the upper and lower accessory drive gears, the two idler drive gears, and the intermediate gear shaft. The nuts holding the dual accessory housing to the rear cover will then be exposed.

Break the lock wire and remove the two acorn nuts and washers from the two studs which extend from the bottom of the accessory drive housing through the supercharger

rear housing and cover parting flanges. Remove the special cap nut from the upper right side of the housing. Break the lock wire and remove the two shouldered nuts and washers located under the overhanging flange of the housing and the nut in the upper right corner. Use offset box wrench, Tool No. 800684. See figure 75. Remove the cotter pin and withdraw castellated nut and washer from the stud through the center of the floor of the housing. Remove the dual accessory drive housing and gasket from the supercharger rear housing cover.

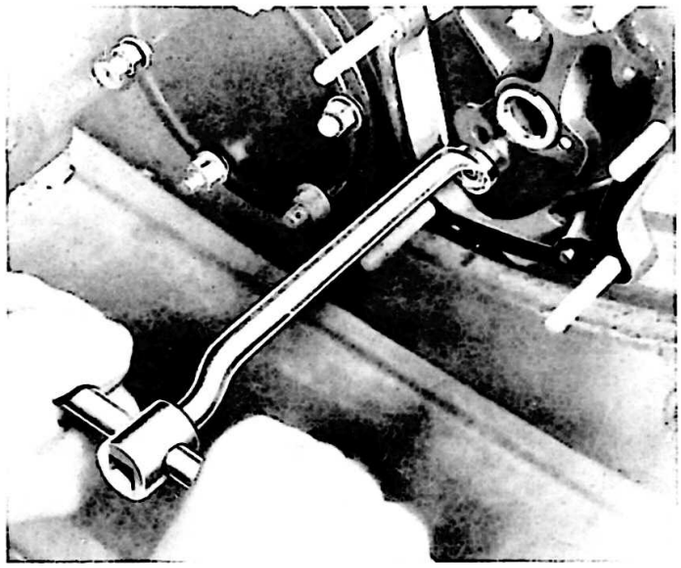


Figure 75—Removing Dual Accessory Drive Hidden Nut

INSTALLATION—Place a gasket over the attaching studs on the dual accessory drive housing mounting pad. Place the housing in position on its attaching studs but do not push it all the way on the mounting pad.

Install the special shouldered nuts and washers on the two studs under the overhanging flange of the housing and the nut in the upper right corner. Install a castellated nut and washer on the stud extending from the supercharger rear cover through the center of the housing. Gradually tighten the four nuts in rotation. Lockwire the lower left shouldered nuts. Lockwire the upper right shouldered nut to a small eye in the floor of the housing. Cotterpin the center castellated nut. See figure 76.

Install the special cap nut and washer at the upper right side of the housing and lockwire the nut to a drilled passageway in the housing. Install acorn nuts and washers on the two studs which extend from the bottom of the accessory drive housing through the countersunk holes in the rear cover. Lockwire the tips of the nuts together.

Install the tongue drive couplings, if used, in the upper and lower accessory drive gears. Mesh the splined end of the intermediate drive shaft with the splined end of the main drive shaft. Place the idler gears in their bushing in the center of the housing. Place the upper and lower accessory drive gears in their blind bushings, meshing their teeth with the teeth of the rear idler gear.

NOTE: The dual accessory drive gears and the intermediate drive gear should be installed simultaneously.

Install a gasket on the dual accessory drive housing parting surface. Place the cover on its attaching studs and slide it over the rear journals of the gears. Install a plain washer and special cap nut on each of the two studs extending from the supercharger rear housing cover through the upper left side of the accessory drive housing and cover. Install a plain washer and elastic stop nut on the cover attaching stud located between the upper and lower drives. Tighten these nuts evenly. Lockwire together the two special cap nuts at the upper left side of the cover. Install the accessories, if used, following their respective manufacturers' instructions. Install the substituting cover, if used, with a gasket, and secure with plain washers and elastic stop nuts. Tighten the nuts evenly.

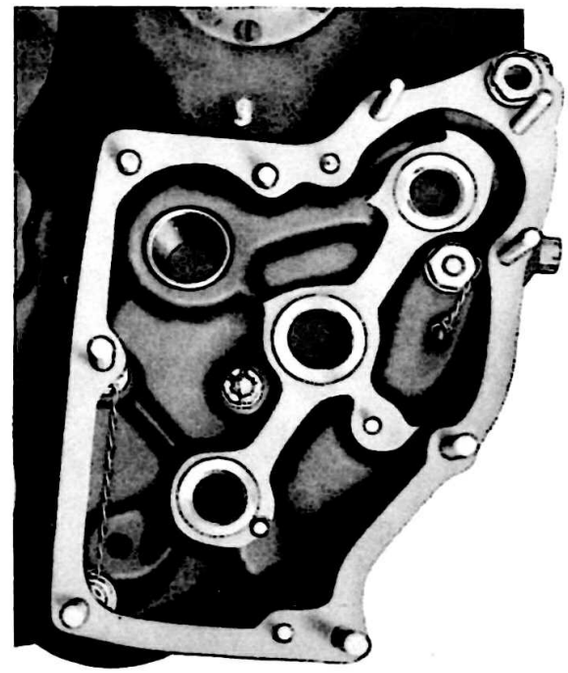


Figure 76—Dual Accessory Drive Housing Nuts Lockwired

GUN SYNCHRONIZER IMPULSE GENERATOR DRIVES REMOVAL—If the engine is equipped with gun synchronizer impulse generator drives, they may be removed as follows: Remove the three cap screws and washers which attach each gun synchronizer impulse generator or gun synchronizer substituting cover at the side of the supercharger rear housing. Remove the gun synchronizer impulse generator or subsituting cover.

Remove the flanged gun synchronizer drive shaft support and drive shaft together from the supercharger rear housing. The shaft may then be separated from the support.

INSTALLATION—Place a gasket on the supercharger rear housing mounting pad and install the flanged gun synchronizer drive shaft support and drive shaft as a unit. Install the gun synchronizer impulse generator, or substituting cover with a gasket. Secure with three cap screws and washers. Tighten and lockwire.

GENERATOR AND MAGNETO DRIVE SHAFT OIL SEALS To replace the generator and magneto drive shaft oil seals, proceed as follows:

REMOVAL—Remove the six cap screws and washers. Remove the oil seal assembly.

INSTALLATION—Set the installing tool, Tool No. 803328, in place over the end of the drive shaft. Apply Lubriplate 130-A to the outer diameter of the tool. Slide the gasket and seal, with the hub end forward, over the tool and onto the shaft. Fasten with lock washers and cap screws. Torque the cap screws to the limit in the Table of Tightening Torque Values.

Handle the part carefully to avoid injuring the rubber sealing surface. Do not permit the installing tool to become nicked. Have the seal at room temperature during installation to prevent cracking the rubber. Once installed, the seal should perform satisfactorily in cold weather.

STARTER SHAFT OIL SEAL REMOVAL—Remove the 12 cap screws and shakeproof lock washers in the starter packing retaining ring. Press down on the coupling while removing the oil seal retainer screws to absorb the spring force. Remove the ring and gasket. Remove the starter oil seal packing ring from the flange of the starter coupling.

INSTALLATION—Replace the oil seal packing ring and insert it against the starter coupling flange. Secure the oil seal in place by reinstalling the gasket, the retaining ring, the 12 cap screws and shakeproof lock washers.

PROPELLER SHAFT THRUST BEARING NUT To replace and check the tightness of the propeller shaft thrust bearing nut, remove the propeller in accordance with the manufacturer's instructions. Slide the bronze rear centering cone forward off the propeller shaft.

To loosen the thrust bearing nut install the lug wrench, Tool No. 82889, then install the propeller shaft turning tool, Tool No. 82284, to absorb shock, and strike the handle of the wrench with a lead mallet. Install the thrust bearing nut and ring assembly observing the following instructions: Check the side clearance of the oil seal rings and the end gap of each ring. See figure 77. Refer to the Table of Limits for the proper clearances. Install the rings in their grooves and lubricate with engine oil.

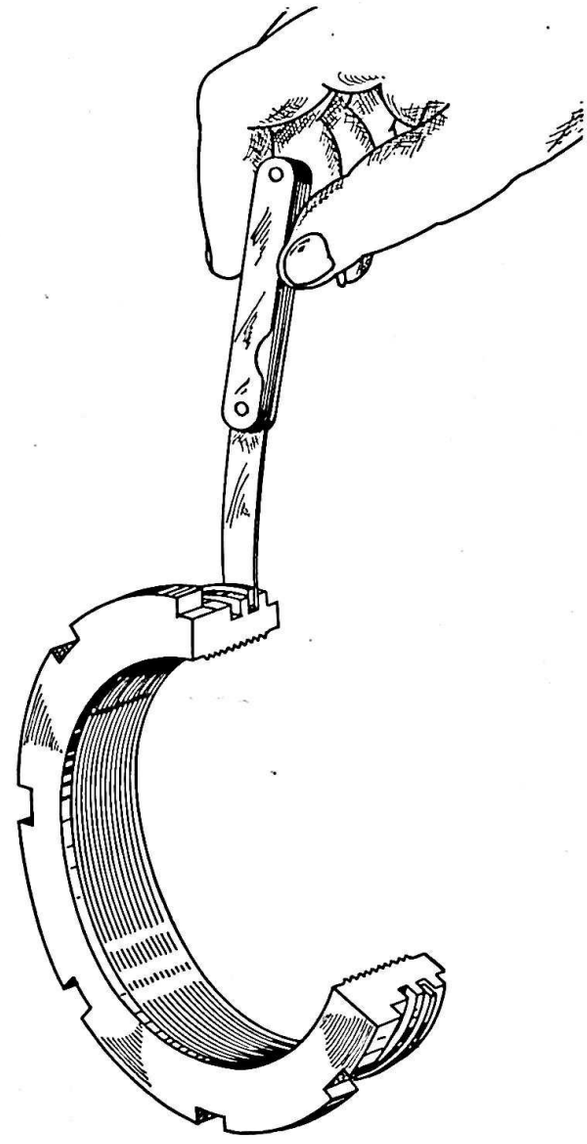


Figure 77—Measuring Thrust Nut Ring Side Clearance

Lubricate the thrust bearing nut threads with anti-seize compound, Aeronautical Material Specification No. 3080. Screw the nut complete with rings on the propeller shaft. Compress the rings with a strip of brass or fiber to avoid damage in installation. Tighten the thrust bearing nut with a lug wrench, Tool No. 82889, and use the propelled shaft turning tool, Tool No. 82284 to absorb shock. Strike the handle with a lead hammer for final tightness. See figure 78. Check with the Table of Limits for correct distance between the holes at the end of the propeller shaft and the front face of the thrust bearing nut. If the dimensions do not fall within these tolerances, replace the thrust bearing nut.

CRANKCASE FRONT SECTION SPACER AND FLANGE (3:2 Reduction Ratio)

REMOVAL—To remove the spacer—when, for example, it is to be replaced by a brush holder for an electric propeller installation—remove the ten castellated nuts and washers and withdraw the spacer from the eight bolts and two studs. Circlets located under the spacer hold the eight stationary reduction gear bolts in place when the spacer and nuts have been removed.

To remove the flange, it will be necessary to remove the propeller shaft thrust bearing nut and ring assembly before removing the ten nuts and spacer. Remove the circlets from the eight bolts and withdraw the flange and gasket. Prevent the bolts from slipping back into the crankcase with a rubber packing ring looped around each bolt.

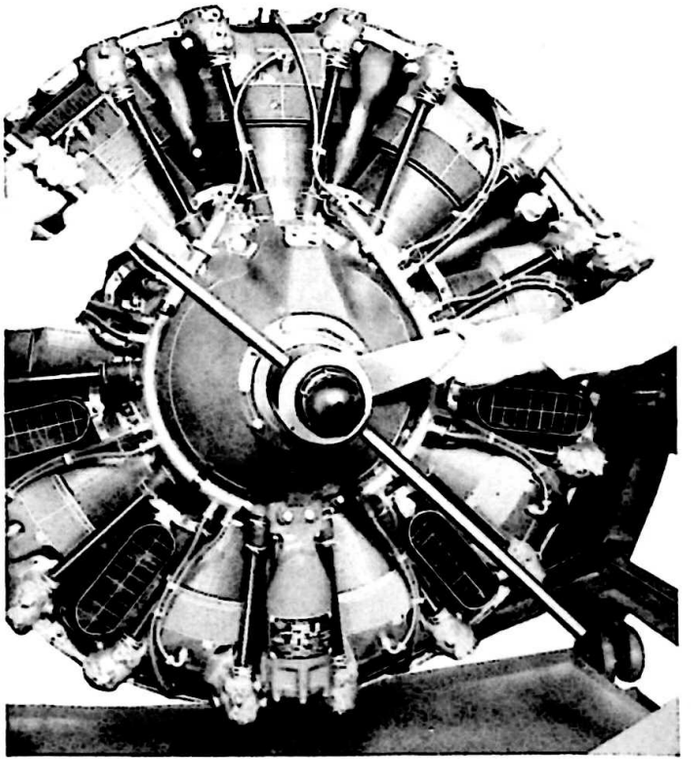


Figure 78—Tightening Thrust Bearing Nut

INSTALLATION—Install a gasket and flange. Make sure the bolts are properly seated in the stationary reduction gear and install circlets on the bolts. Retain the bolts with the rubber packing ring looped around the end of each bolt while performing this operation.

Install the spacer and secure with 10 washers and castellated nuts tightened to the correct torque value as listed in the Table of Limits. Lockwire the nuts in pairs. Install the propeller shaft thrust bearing nut and ring assembly.

CRANKCASE FRONT SECTION SPACER AND FLANGE (16:9 Reduction Ratio)

REMOVAL—To remove the spacer, withdraw the 10 cap screws and washers that secure the spacer, flange, and stationary reduction gear to the crankcase front section and withdraw the spacer. The stationary reduction gear in the 16:9 propeller reduction gear ratio is retained in position by two bolts and washers inserted through the crankcase front section under the flange.

To remove the flange, remove the propeller shaft thrust bearing nut and ring assembly before removing the 10 cap screws and spacer. Remove the cap screws, washers, spacer, and flange.

INSTALLATION—Install a gasket, flange, and spacer on the crankcase front section and secure with 10 washers and cap screws. Tighten the cap screws to the correct torque value and lockwire in pairs. Install the propeller shaft thrust bearing nut and ring assembly.

PROPELLER SHAFT AND CRANKSHAFT RUN-OUT CHECK

Whenever the rotation of a propeller is abruptly stopped or momentarily impeded by the airplane nosing up, crashing, or taxiing into an obstruction or by having the propeller hit a foreign object during take-off or flight, it is necessary to check the propeller shaft and crankshaft run-out, in accordance with the procedures outlined below and to magnetically inspect the reduction driving gear assembly since there is a possibility that the engine has been damaged internally. This internal damage may include cracked gear teeth, crankshaft misalignment, damaged bearings, etc.

PROPELLER SHAFT RUN-OUT CHECK

The propeller shaft should be checked while the engine is installed in the airplane as follows:

1. Make sure the ignition switch is in the "OFF" position.

2. Remove the propeller according to the manufacturer's instructions.

3. Fabricate a tool similar to the one shown in figure 80. The tool is made in two sections, each with internal threading at one end, external threading at the other, and a 3/8 inch diameter shank.

Attachment to the engine is made by removing one of the crankcase front cover attaching nuts and installing the arm on the bolt threads. With externally installed bolts the bolt is removed and the arm installed in its place. The two sections, singly or in combination, may be installed on 3/8 inch threads directly, and on 7/16 inch threads with the aid of an adapter.

4. Install the tool on the engine and assemble the dial indicator to the tool as shown in figure 79.

5. "Zero" the dial indicator and rest it just forward of the spline on the propeller shaft, then turn the crankshaft with the starter three times, note the reading and record the maximum run-out on each side of the zero registered on the indicator during each revolution of the propeller shaft and total the readings. The average of the sums of these readings is the propeller shaft run-out. Refer to the applicable Table of Limits for the allowable run-out tolerances.

6. Remove the dial indicator and remove the tool from the thrust flange spacer.

7. Replace the nut or bolt on the thrust flange spacer.

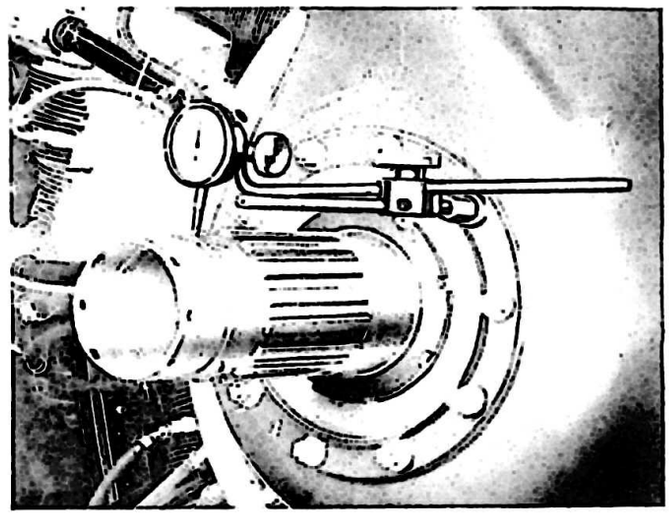


Figure 79—Taking Propeller Shaft Run-Out

CRANKSHAFT RUN-OUT CHECK

The crankshaft run-out should be checked while the engine is installed in the airplane as follows:

1. Loosen the propeller shaft thrust nut, and remove the crankcase front section assembly in accordance with existing instructions.

2. Install the adapter, tool, and dial indicator to the crankcase main section, at the crankcase main to crankcase front section attaching cap screw position.

3. "Zero" the dial indicator and place it so that read-

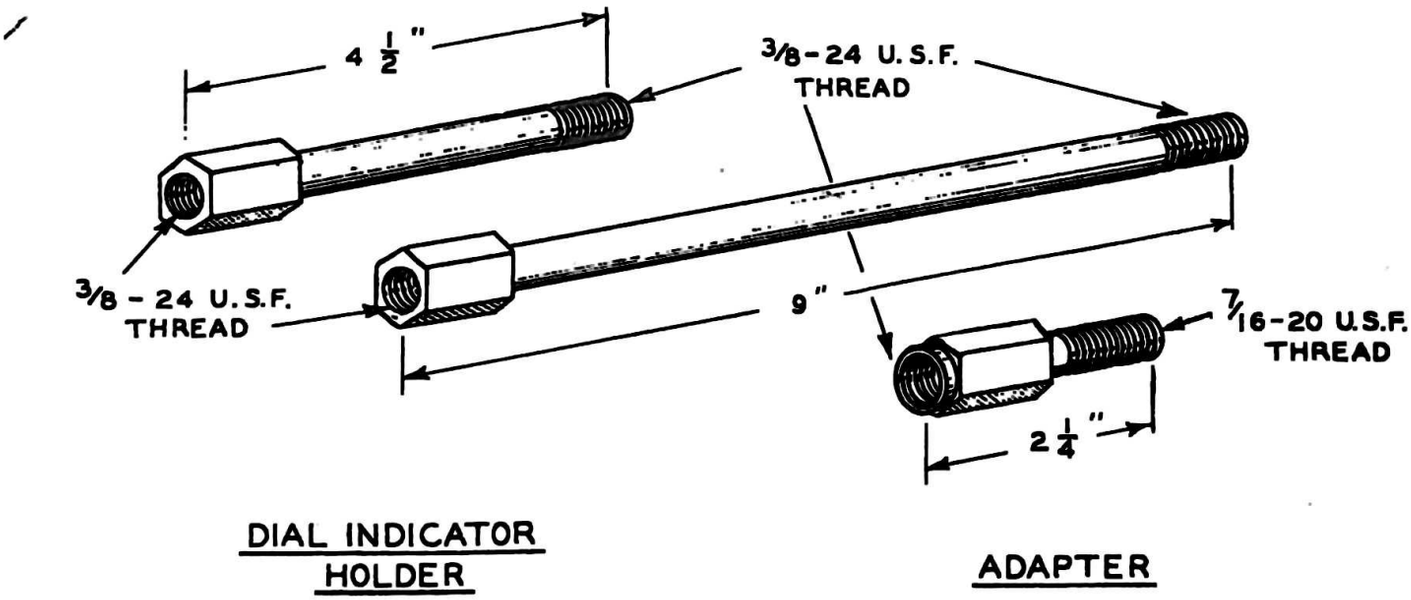


Figure 80—Tool for Propeller Shaft Run-Out

ings may be obtained at the propeller shaft front bushing journal.

4. Turn the crankshaft three times with the starter. Record the maximum run-out on each side of the zero as registered on the indicator during each revolution of the crankshaft. Total these readings. The average of the sums of these readings is the propeller shaft front bushing journal run-out.

5. Move the dial indicator so that it seats on the propeller shaft rear bushing journal and repeat the procedure used at the front journal.

6. If the crankshaft run-out is greater than the allowable tolerance as shown in the Table of Limits, the engine must be removed and overhauled.

INSPECTION 1. Disassemble the crankcase front section and perform a magnetic inspection of the reduction driving gear assembly.

2. Inspect the thrust bearing for signs of damage.

3. Check all oil sump plugs and oil strainers for metal particles denoting internal damage to the engine. If such signs are evidenced, the engine must be removed and overhauled.

4. Inspect the items listed below in accordance with the 100-hour inspection procedure:

a. Carburetor attachment
b. Engine exterior
c. Exhaust system
d. Fuel strainers
e. Intake pipes
f. Magnetic sump plug and the drain plug
g. Oil strainers

5. After inspection, if no signs of internal damage have been found or no serious external damage noted, the crankcase front section may be assembled and installed on the engine in accordance with existing instructions.

PROPELLER SHAFT HYDRO-OIL FITTINGS To uncover the hydro-oil passages in the propeller shaft—for inspection purposes or for installation of a hydromatic propeller—proceed as follows: Remove the three fillister head screws and washers securing the brass lock plate to the substituting cover nut and withdraw the lock plate. Remove the nut using the special wrench, Tool No. 804671, and withdraw the hydro-oil connection substituting cover and gasket. The hydro-oil connection adapter and gasket may now be withdrawn for inspection purposes, and reinstalled with new gasket.

The hydro-oil connection substituting cover with its nut and brass lock plate are not used with a hydromatic propeller installation. When an electric propeller is employed, the substituting cover and gasket should be reinstalled with its nut and brass lock plate. Lockwire the three fillister head screws and washers securing the lock plate. See figure 81.

The above instructions apply to crankcase breathing engines only. In engines that breathe through the crankshaft the hydro-oil connection may be made after removing the oil connecting plug and washer from the fittings in the front of the propeller shaft. The hydro-oil connection in the shaft may be inspected after removing the breather screen and nut following instructions for removal of the brass lock plate and nut, above.

TORQUEMETER BOOSTER PUMP REMOVAL — Remove the attachments securing the propeller governor and booster pump to the four attaching studs on the mounting pad of the crankcase front section. Remove the propeller governor and gasket. Remove the booster pump and gasket.

INSTALLATION—Install a gasket over the four attaching studs on the mounting pad of the crankcase front section and install the booster pump as a unit. Install a gasket and install the propeller governor. Secure the booster pump, gaskets, and propeller governor to the four studs with the proper attachments.

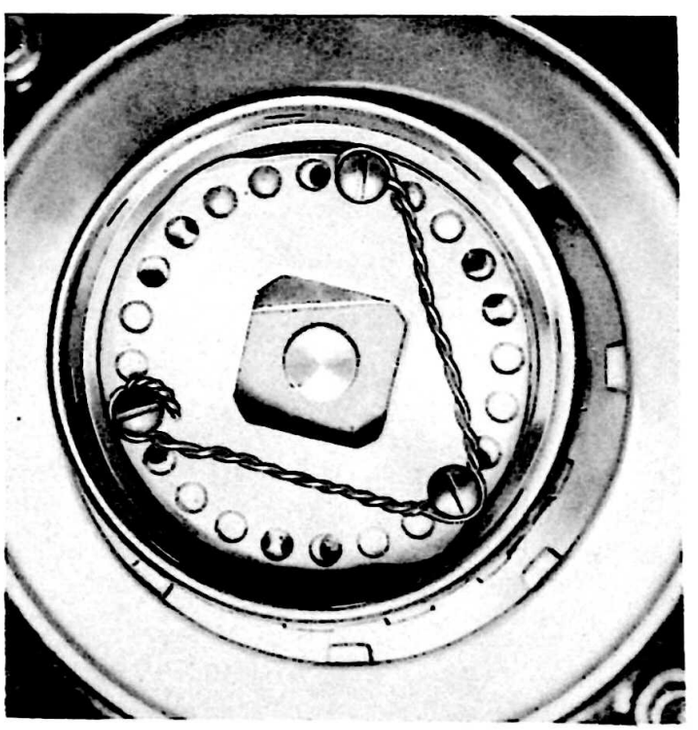


Figure 81—Lock Plate in Propeller Shaft Lockwired

TORQUEMETER REMOVAL—Detach the brake mean effective pressure line. Remove the eight nuts and bolts securing the torquemeter housing cover and remove the cover and gasket. Withdraw the valve with ring from the housing.

INSTALLATION—Lubricate the valve ring with engine oil. Install the ring on the valve and position the ring and valve on the cover using a new gasket. The ring gap should be positioned between the two oil metering slots on the cover. Then install this assembled unit of cover, ring, and valve into the housing. Be extremely careful in placing the valve stem in its proper position through the hole of the torque arm.

Secure the assembly with eight nuts and bolts and lockwire in series of two.

Connect the brake mean effective pressure line.

SECTION VII

PREPARATION FOR STORAGE AND SERVICE

While complete compliance with the following instructions may at times be impracticable, the more completely they are followed the less probability there will be of corrosion and the failure of engine parts caused by corrosive action.

All engines which are to be stored or to remain idle for periods exceeding 24 hours MUST be protected to prevent corrosion of metal parts. Protection is afforded by ground running the engine once every day or (a) running the engine out on unleaded fuel, (b) slushing the internal sections of the engine with a preservative compound, and where possible, (c) dehydrating the air in and around the engine by means of a dehydrating agent and a moisture-resistant transparent plastic-film envelope. It is the purpose of this section to outline the procedure necessary to provide such protection and, although the chronological order of the following instructions may be changed, each operation should be performed. Engines not protected with envelopes should be reslushed at least every six months. If stored near tidewater or in a tropical climate, repeat the procedure at three-month intervals.

Slush engines which cannot be turned over due to inter-

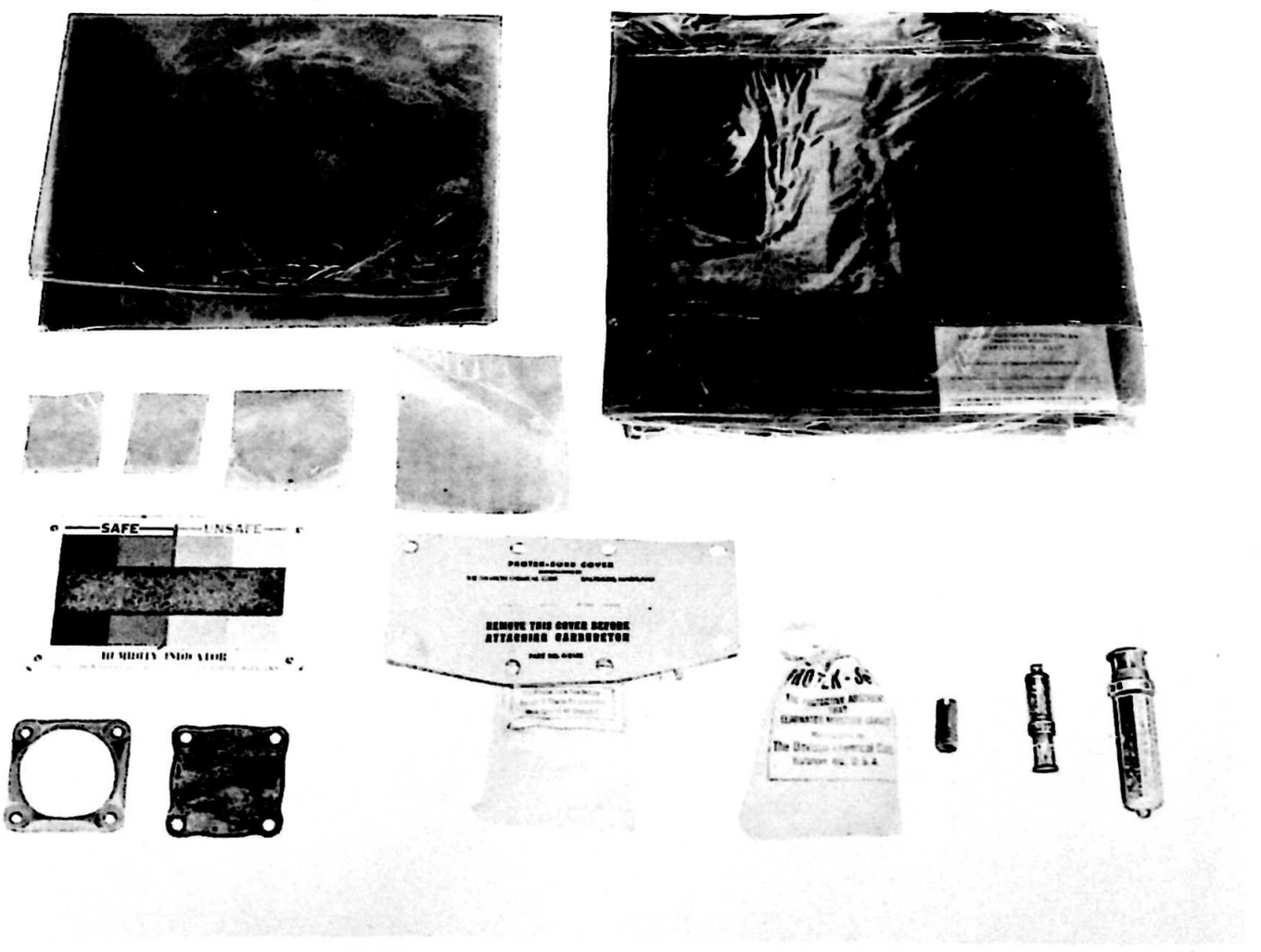


Figure 82—Engine Packing Equipment

nal failure in any practical manner to keep the engine parts in as good condition as possible.

When any accessories are removed from the engine, treat them as recommended by their manufacturers. Coat the mounting pad recesses with a slushing mixture conforming to Aeronautical Material Specification No. 3072, and seal the pads securely with moisture-resistant gaskets and substituting covers. See figure 82 which shows the engine packing equipment.

TABLE FOR RUN-OUT AND SLUSHING PROCEDURE

1. Change the fuel to unleaded fuel.
2. Drain the oil from the engine and the tank.
3. Refill with sufficient corrosion-preventive compound for safe engine operation. The compound must conform to Aeronautical Material Specification No. 3072.
4. Run the engine for 15 minutes at 1000 rpm maximum with the propeller in low pitch (high rpm). Just prior to shutting down, hydraulically spray slushing mixture into the induction system either through the carburetor, carburetor adapter, or any convenient connection in the induction system between the airscoop and the impeller.
5. When the exhaust smoke becomes very heavy, set the mixture control in "CUT-OFF" and continue to spray until the engine stops. Turn the ignition switch to the "OFF" position.
6. Remove the front spark plugs from all the cylinders and replace them with vented dummy plugs.
7. Remove the magnetic sump plug and let the slushing compound drain from the sump.
8. Remove the exhaust stacks. Hydraulically spray the exhaust valves and ports with slushing compound conforming to Aeronautical Material Specification No. 3072, and cover them with moisture-resistant seals.
9. Remove the rocker box covers and hydraulically spray the rocker arm assemblies and covers with slushing compound conforming to Aeronautical Material Specification No. 3072. Reinstall the covers.
10. Before slushing the carburetor open the throttle wide. Set the mixture control at "AUTO-RICH". Permit no slushing oil to enter the regulator air chambers, the air passages, or the automatic mixture control. These locations must be kept dry at all times. Do not use air pressure to clean the carburetor.

If the carburetor is to remain installed on the engine, disconnect all fuel lines. Close the openings of the fuel lines with synthetic rubber plugs or an equivalent. Remove the drain plugs and pour lubricating oil, conforming to Aeronautical Material Specification No. 3070, into the carburetor fuel inlet connection. See figure 83. Continue this treatment until the oil draining from the carburetor is of the same consistency as that of the oil being poured into it. After the carburetor has been drained of excess oil, reinstall and lockwire the drain plugs.

11. Remove the vented plugs.
12. With each piston at the bottom of the stroke hy-

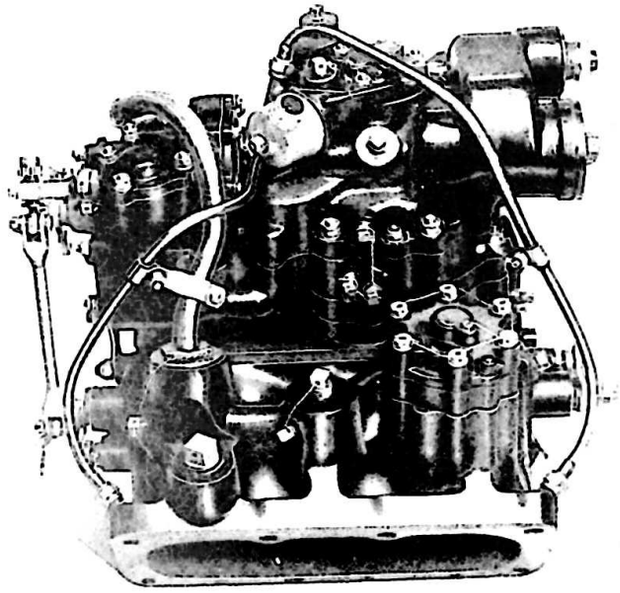


Figure 83—Stromberg Carburetor Drain Plugs

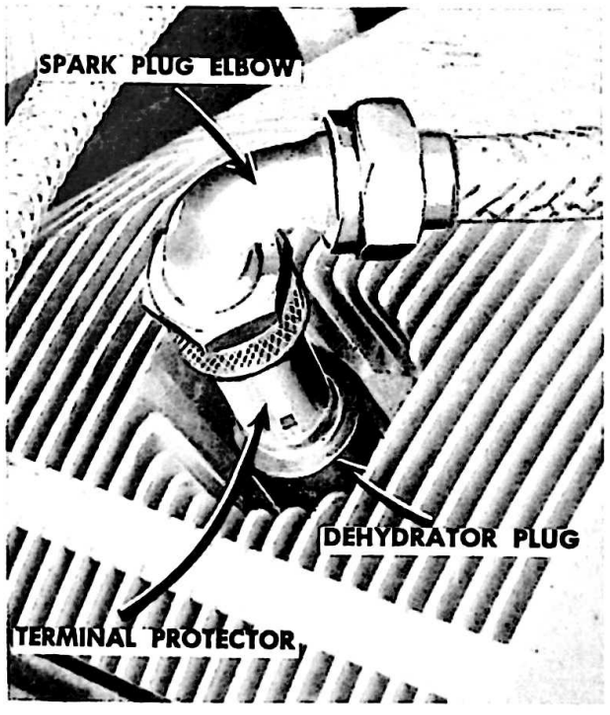


Figure 84—Spark Plug Terminal Protector

draulically spray the inside of the cylinder. Experience in performing this operation indicates that spraying with compressed air is very unsatisfactory due to the difficulty of removing all moisture from compressed air. Moisture in the spray results in a corrosive action developing in the treated parts. It is therefore recommended that all spraying for corrosion prevention be accomplished hydraulically. The equipment necessay for hydraulic spraying consists of a container for hot oil, 79° to 107°C (175° to 225°F), a pump capable of maintaining oil at a pressure of 90 pounds per square inch (6.83 kilograms per square centimeter) against the flow through a No. 40 nozzle, an oil pressure relief valve set at not less than 90 pounds per square inch (6.83 kilograms per square centimeter), an adapter for the nozzle, and a No. 40 oil burner nozzle, as well as sufficient high pressure hydraulic hose and a shut-off valve.

13. After this operation, without rotating the shaft, spray a small amount of compound into each cylinder.

14. Remove all plugs.

15. Install the crankcase dehydrating plug.

16. Install the cylinder dehydrating plugs, two to each cylinder, and using the spark plug terminal protectors and covers connect the ignition leads to the dehydrator plugs. See figure 84.

17. Wash the engine thoroughly with a petroleum solvent conforming to Aeronautical Material Specification No. 3160, or if such a solvent is not available, use a wash gasoline. Keep the solvent or gasoline away from the magnetos and all braided leads.

18. Dry the engine with compressed air.

CAUTION: Do not begin preparing the engine for storage or shipment until it is certain that the entire procedure can be completed without delay.

PREPARATION FOR STORAGE OF OPERABLE ENGINE TO REMAIN IN AIRCRAFT

LESS THAN 7 DAYS Operate the engine each day until normal oil-in operating temperature is reached. In cold climates operation of the engine may cease at one-half hour if normal oil-in operating temperature cannot be reached. This treatment is limited to seven consecutive days at the termination of which the plane must be flown or the engine must be prepared for storage.

7 TO 30 DAYS Refer to the TABLE FOR RUN-OUT AND SLUSHING PROCEDURE and perform every operation except 8. Cover all breathers and vents with moisture-resistant seals. Attach a one-pound bag of dehydrating agent in the carburetor air scoop, and one in the exhaust system opening, if space permits. Cover both openings with moisture-resistant seals and place a dehydrating agent warning card at each location.

MORE THAN 30 DAYS Refer to the TABLE FOR RUN-OUT AND SLUSHING PROCEDURE and perform every operation except 8. Cover all breathers and vents with moisture-resistant seals. Disconnect and plug all oil-in and oil-out lines. Attach a one-pound bag of dehydrating agent in the carburetor air scoop and one in the exhaust system opening, if space permits. Cover both openings with moisture-resistant seals and place a dehydrating agent warning card at each location.

Cover the engine with the cover furnished by the aircraft manufacturer.

CAUTION: Inspect the dehydrator plugs weekly and replace them when a comparison of their color with the colors of a humidity indicator card indicates more than 20 percent humidity.

PREPARATION FOR SHIPMENT OR STORAGE OF OPERABLE ENGINE TO BE REMOVED FROM AIRCRAFT

MORE THAN 30 DAYS Refer to the TABLE FOR RUN-OUT AND SLUSHING PROCEDURE and perform every operation. At some time during the procedure it will be necessary to remove the engine from the aircraft and place it in a disassembly stand. This may be done at the discretion of the operator.

Cover all breathers and vents with moisture-resistant seals.

Install the gasket and dehydrator bag assembly on the carburetor mounting pad and seal the induction passage tightly with a moisture-resistant seal.

Install the oil tank vent sump in the oil tank vent connection on the supercharger rear housing cover. See figure 85. Lockwire the removed plug to any nearby location.

Raise the engine from the disassembly stand.

NOTE: Do not handle plastic-film at low temperatures as it cracks and breaks easily when cold. Just prior to using this material it should be placed in a warm room to make it pliable. The best temperature for working plastic-film is above 21°C (70°F).

Wrap heavy paper around the circumference of the supercharger rear housing. Lift the plastic-film envelope loosely over the supercharger rear housing and attach temporarily to the cylinders. Secure the mounting plate to the engine, being careful not to tear the envelope. See figure 86.

Remove the four hold-down bolts securing the shipping box cover to the bottom section. Lift off the cover of the shipping box. Install the wood box in which the carburetor is packed after slushing as described in this section, in the cover of the shipping box. Secure it firmly to the shipping box cover.

Slush all unattached parts with the corrosion-preventive mixture, Wright Aeronautical Corporation Specification No. 5842D. Pack these parts in the space provided between a cradle member and the end of the box. Secure the cover with nailed cleats.

Lower the engine with the mounting plate into the cradle. Assemble all nuts and washers on the hold-down bolts to secure the mounting plate tightly on the cradle.

Remove the propeller shaft lifting eye and coat the propeller shaft internally and externally with slushing com-

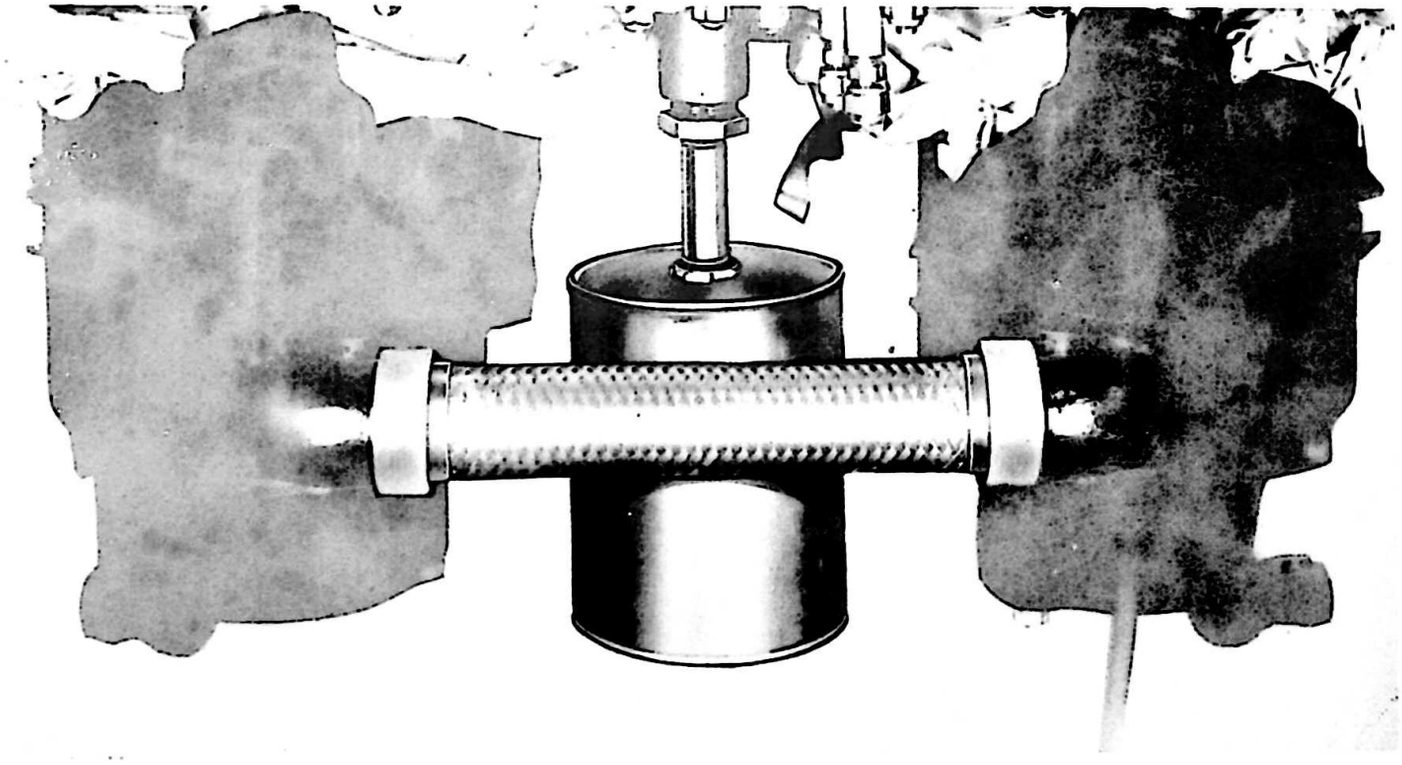


Figure 85—Oil Tank Vent Sump Installed in Supercharger Rear Cover

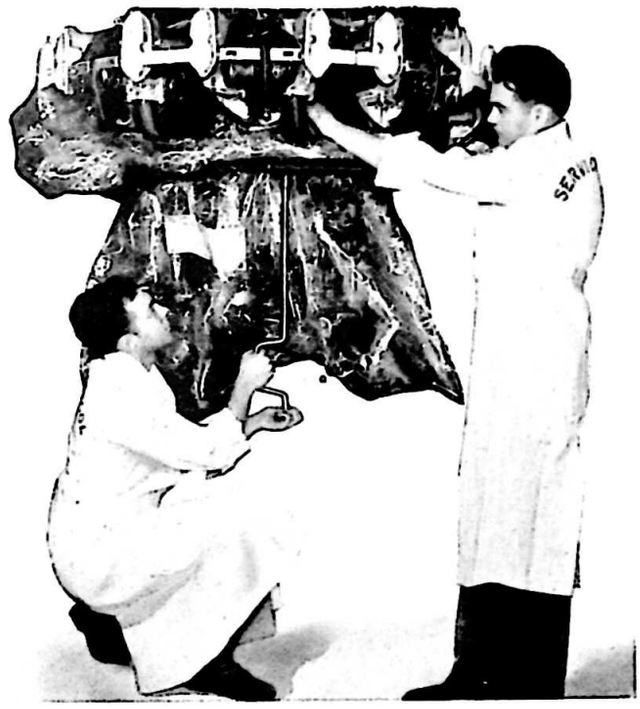


Figure 86—Securing Mounting Plate to Engine

pounds conforming to Aeronautical Material Specifications No. 3072 and 3075 respectively. Install the protective cap on the front end of the shaft. Wrap the shaft in a greaseproof, acid free wrapper and secure with adhesive tape.

Arrange 13 one-pound (.4536 kilogram) bags conforming to Aeronautical Material Specification No. 3420 of dehydrating agent around and between the cylinders and fasten securely so that the bags will not rub or chafe the plastic-film envelope during shipment.

Wrap heavy paper around the circumference of the engine at the cylinder heads and place the humidity indicator between the plastic-film envelope and the wrapping, so located as to be clearly visible from the inspection port in the shipping box cover. See figure 87.

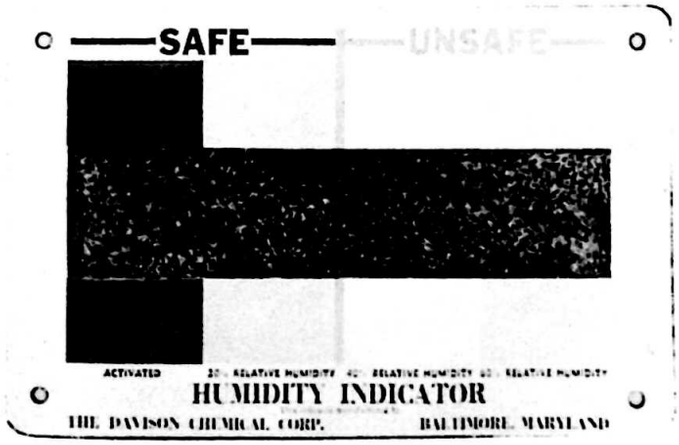


Figure 87—Humidity Indicator

Roll the plastic-film envelope up over the propeller shaft. Make certain that the envelope is drawn around the engine very loosely so that it will not chafe.

Heat seal the envelope by bringing the open edges of the envelope together over the top of the engine and using the sealing iron, Tool No. 802924, at 163° to 177°C (325° to 350°F). Seal the open edges over a one-half inch (12.7 millimeters) wide area about ¼ inch (6.35 millimeters) from the edge of the cut. A board covered with cardboard may be used to back up the material when the iron is run over it.

While completing the sealing operation, slightly deflate the envelope and inspect it to see that no ruptures have occurred. A ruptured envelope must be resealed. Inspect the seam; if well sealed it will be transparent through its length. A poor seam in which the iron was not the right temperature or the surfaces were not pressed together will be cloudy or filmy. A poor seam should be repaired. Do not use too hot an iron as the envelope may be cut at the sides of the seam.

After the sealing is finished, fold the excess material around the engine and secure it with tape so that there is no more than one thickness of envelope film between the humidity indicator card and the inspection port in the side of the shipping box.

There will be sufficient material in the upper part of the envelope to cut off the sealed edge when the engine is removed. This excess material permits the envelope to be used five or six times.

Whenever a failure occurs that will permit the entrance of moisture into the envelope, inspect the indicator thoroughly and if it shows a safe color, reseal the envelope as previously instructed, or with any moisture-resistant sealing tape. If the indicator shows an unsafe condition, replace the dehydrating agent before sealing the envelope.

After treating all accessories which have been removed from the engine as instructed by their manufacturers, place each of them with a one-pound bag of dehydrating agent in individual plastic-film envelopes. Care must be taken not to break or chafe the envelope. Secure the accessories in the cradle of the shipping box.

Lower the shipping box cover over the engine and secure it to the cradle with the four hold-down bolts. See figure 88. Seal two diagonally opposite bolts.

Shipping boxes that contain engines should be suitably

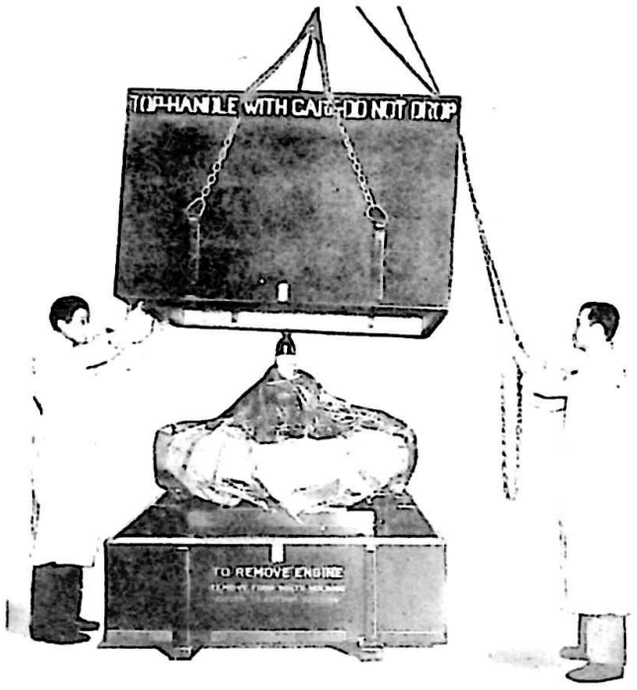


Figure 88—Lowering Shipping Box Cover

protected from the elements and where possible should be stored indoors.

PREPARATION PRIOR TO DISASSEMBLY OF ENGINE INSTALLED IN AIRCRAFT OPERABLE ENGINE—If the engine is to be disassembled within 24 hours, no run-out or slushing is necessary. If not, determine the length of time it is to remain assembled and treat as instructed under that section.

INOPERABLE ENGINE—No preliminary treatment is necessary if the engine is to be disassembled within 24 hours, otherwise, remove it from the aircraft, place it on a disassembly stand, and perform as many of the following operations as possible.

Place the engine front end up, remove the timing inspection plug, and fill the engine with slushing mixture conforming to Aeronautical Material Specification No. 3072.

Reinstall the timing inspection plug, place the engine front end down for 15 minutes to slush the front section, and then place the engine in flight position and drain the sump.

Remove the rocker box covers. Hydraulically spray the rocker arm assemblies and covers with slushing mixture conforming to Aeronautical Material Specification No. 3072. Reinstall the covers.

Remove the oil tank vent plugs from the supercharger rear housing and spray the gears with slushing mixture conforming to Aeronautical Material Specification No. 3072. If possible, rotate the crankshaft during this operation.

Hydraulically spray hot, 79° to 107°C (175° to 225°F), slushing mixture conforming to Aeronautical Material Specification No. 3072, through the spark plug holes into the combustion chambers.

Remove the exhaust stacks, hydraulically spray the exhaust valves and ports with slushing compound conforming to Aeronautical Material Specification No. 3072, and cover them with moisture-resistant seals.

GENERAL PRECAUTIONS HUMIDITY INDICATOR CARD—Inspect the engine humidity indicator card once every two to four weeks. Climatic conditions may necessitate a more frequent check. If the indicator shows an unsafe color, replace it and the dehydrator bags. At the same time, replace the crankcase and cylinder plugs if the color of their content denotes an unsafe condition. While making this inspection, repair any tears or ruptures that may be found in the transparent envelope.

If the dehydrating agent is exposed to the air for more than a few minutes, it must be discarded. Do not break the dehydrator seals until just prior to installation in the engine.

PACKING BOX The Cyclone 9HC engines are enveloped in plastic-film and packed for shipment in vertical position in a shipping box having the following dimensions: length 65 inches (1651 millimeters), width 61 inches (1550 millimeters), height 59 inches (1449 millimeters). The approximate total weight of the shipping box with the engine packed for shipment is 2200 pounds (997.92 kilograms).

The shipping box is constructed in two sections, a cradle on which the engine is mounted and in which unattached parts are stored and a cover which is bolted to the cradle. Two steel straps on each of the two opposite sides of the cover form lifting hooks and provide means of bolting the cover to the cradle section.

TREATMENT OF SUBMERGED ENGINE Do not raise the engine until preparations for its immediate treatment are completed. It is necessary that all parts be washed in unleaded gasoline and coated with slushing mixture conforming to Aeronautical Material Specification No. 3072 or 3075, or any other available compound, as soon as the engine is disassembled.

SLUSHING AND PACKING OF SPARE PARTS Spare parts to be packed for shipment or storage should first be washed with a petroleum solvent conforming to Aeronautical Material Specification No. 3160, or a wash gasoline, and then slushed with a compound conforming to Aeronautical Material Specification No. 3075. Coat all surfaces, and allow to drain and dry for at least one hour. Wrap with material conforming to Aeronautical Material Specification No. 3540 or 3542. Store in a dry place. Parts to be shipped must be packed in suitable boxes with slings, blocks, or sufficient dunnage to prevent shifting. Specially constructed boxes are required for most large parts. Coat antifriction bearings with grease and wrap in greaseproof paper.

REMOVING ENGINE FROM SHIPPING BOX AND PREPARING FOR SERVICE Break the seals and remove the four bolts from the metal straps on the shipping box. Attach a hoisting cable, Tool No.84392, to the hooks on the metal straps and remove the shipping box cover. Slit the plastic-film envelope along the top seam and roll the envelope down over itself to the engine mounting plate. Since the envelope may be used several times, care should be taken in opening and removing it.

Remove all the dehydrating bags from the cylinders and remove the humidity indicator. Remove the bag and thread-protecting cap from the propeller shaft, install a turning bar on the propeller shaft, and reinstall the thread-protecting cap.

Remove the cylinder dehydrating plugs to allow the slushing compound to drain from the cylinders and lower intake pipes. Turn the propeller shaft through at least five revolutions to assist drainage and reinstall the dummy or dehydrating plugs.

Remove the thread-protecting cap and turning bar and install the engine hoisting eye, Tool No. 83761. Attach the hoist to the eye. Remove the nuts which secure the mounting plate to the cradle. Raise the engine and mounting plate from the shipping box. Remove the mounting plate and the plastic-film envelope from the engine. Remove the oil tank vent sump and adapter from the rear cover and install the plug which is wired nearby. Lockwire the plug.

Secure the metal straps of the engine hoisting sling to the cowl attaching studs at the front and rear of the intake rocker boxes of cylinders No. 1 and 9, using eight lock washers and nuts. See figure 89. Insert the spreader bar between two arms of the cradle assembly, and tighten the cable clamps before hoisting. The spreader bar must always be in position before an attempt is made to hoist the engine by means of this sling. Raise the engine to the flight position.

Remove the sump dehydrator plug and allow the sump to drain. Install the magnetic plug and lockwire. Remove the oil strainer, immerse in gasoline, rotate, and blow out with compressed air. Repeat this operation until the strainer is thoroughly clean. After cleaning, lubricate by immersing in clean engine oil and blowing out with compressed air.

Remove all miscellaneous engine-opening seals from the engine. Remove exhaust port seals from the engine before installing stacks. Remove the supercharger drain valve, clean, and reinstall. Remove the dehydrator bag and gasket assembly from the carburetor mounting pad before installing the carburetor.

Before installing, treat the accessories as recommended by their manufacturer. Pre-oil the engine following the instructions in section III.

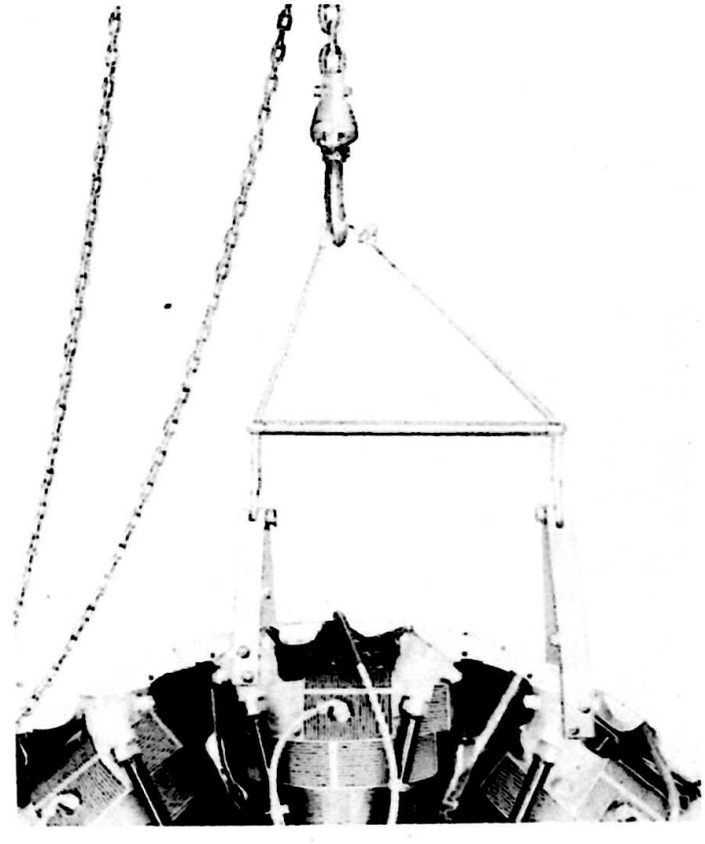


Figure 89—Using an Engine Hoist Sling

SECTION VIII

SERVICE TOOLS

ENGINE TOOL KIT TOOLS

Tool No.	Nomenclature
80540	ROLL—Tool kit tool
81132	SCREWDRIVER—Valve clearance adjusting screw
81403	HANDLE—7/16 in. (11.11 mm) dia., hollow
81405	GAGE—Feeler
81900	WRENCH—Valve clearance adjusting and rocker arm clamp screw
84458	WRENCH—Spark plug socket, 7/8 in. (22.23 mm) hex.
800630	WRENCH—Spark plug terminal elbow, crowfoot, 3/4 in. (19.05 mm) hex.
800687	PLIERS—Push rod housing hose clamp, removing and installing
801122	WRENCH—Push rod housing hose clamp, socket, 1/4 in. (6.35 mm) hex.
801999	WRENCH—Oil pressure relief valve nut adjusting, socket, 1-3/8 in. (35.93 mm) hex.
802293	WRENCH—Cylinder hold-down cap screw, box, 1/2 in. (12.7 mm) hex.
802870	COMPRESSOR—Valve spring
803774	GUN ASSEMBLY—Ignition system insulating compound injecting
803882	WRENCH—Intake pipe packing nut, lug

ADDITIONAL TOOLS

(Usually Available at Service Stations)

Tool No.	Nomenclature
80292	HANDLE—Propeller shaft turning tool
80440	CLAMP—Piston ring
82284	TURNING TOOL—Propeller shaft (Used with two handles, Tool No. 80292)
82703	REMOVING TOOL—Push rod (Used with handle, Tool No. 81403)
82889	WRENCH—Propeller shaft thrust nut, lug
83532	PLUG—Timing disk expansion (3-jaw)
83596	PLATE—Master and articulated rod guide
83660	WRENCH—Oil pressure relief valve body, two lug
83764	EYE—Propeller shaft and engine hoist
84329	SLING—Complete assembly, engine hoist
84770	REMOVING TOOL—Rocker box cover washer, magnetic
84922	WRENCH—Torque, 1200 in. lb (1385 cm kg)
84956	PULLER—Fuel pump drive shaft support, removing
800684	WRENCH—Oil pump foot nut and dual accessory drive housing hidden nut
800821	WRENCH—Supercharger drain valve body tee handle socket
800907	COVER—Intake pipe packing nut
800910	COVER—Cylinder exhaust port
801082	EXPANDER—Timing disk plug (3-jaw)
801083	DISK—Timing
801225	INSTALLING TOOL—Fuel pump drive shaft oil seal, arbor press
801534	PULLER—Fuel pump drive shaft oil seal, removing
802177	SCREW—Cylinder to crankcase, locating
802726	ADAPTER—Valve tappet guide (Used with puller, Tool No. 802242)
802242	PULLER—Multi-purpose impact, removing
802700	WRENCH—Double handle, torque, 7200 in. lb (8309 cm kg)
802919	PULLER—Exhaust valve guide spacer retainer
802924	SEALER—Plastic-film heating iron
803145	CLAMP—Piston ring (Used for simplex spring loaded piston rings)
803299	REMOVING TOOL—Piston pin
803562	EXPANDER—Timing disk plug (12-jaw)
803563	PLUG—Timing disk expansion (12-jaw)
803777	INSTALLING TOOL—Valve tappet circlet
803829	GUN ASSEMBLY—Ignition system insulating compound injecting
804177	INDICATOR—Top center
804351	COVER—Cylinder intake port
804448	PLIERS—Magneto block and wire fastening washer assembling
804671	WRENCH—Propeller shaft hydro-oil connection cover nut (Used with torque wrench, Tool No. 802700)

APPENDIX I

RELEASED MATERIALS AND ACCESSORIES

The Wright Aeronautical Corporation conducts a continual investigation of a large number of materials and accessories to determine which may be used with each model of Cyclone 9HC engines without impairing or adversely affecting the proper functioning or reliability of the engine. Certain materials and accessories thus investigated have been released by the Wright Aeronautical Corporation for use with each model of Cyclone 9HC engines. Such a release signifies that the specified material or accessory may be used with the specified engine model without thereby voiding the engine guarantee. The use of materials and accessories not released by the Wright Aeronautical Corporation constitutes a misuse of the engine and voids the guarantee.

The release of a material or accessory by the Wright Aeronautical Corporation is not a guarantee by the engine manufacturer of the durability or satisfactory operation of a material or accessory, inasmuch as they are usually guaranteed separately by their respective manufacturers.

Two classifications of released materials and accessories exist:

1. Materials and accessories supplied but not manufactured by the Wright Aeronautical Corporation, such as carburetors, magnetos, oil strainers, ignition wire, and ignition wiring harnesses. Materials and accessories in this classification are released only when procured from the Wright Aeronautical Corporation or through its authorized agents. Replacement parts for released accessories in this classification must be procured from the accessory manufacturer or through the authorized agents of that manufacturer or from the Wright Aeronautical Corporation or through its authorized agents. Adequate service instructions for these accessories will be furnished by the accessory manufacturer upon request.

2. Materials and accessories neither manufactured nor normally supplied by the Wright Aeronautical Corporation, such as fuels, lubricating oils, spark plugs, fuel pumps, starters, generators, alternators, vacuum pumps, and hydraulic pumps. Spark plugs, although supplied by the engine manufacturer with new engines, are handled as an accommodation only. Whenever possible, spark plugs should be purchased directly from the spark plug manufacturer or through that manufacturer's authorized representative. Replacement parts for released accessories in this classification must be procured from the accessory manufacturer or through the authorized agents of that manufacturer.

All released materials and accessories in group one are listed in the parts catalogs, parts lists, or other publications of the Wright Aeronautical Corporation.

A wide selection of released materials and accessories in group two is available for each engine model and installation. A complete list of these items is not published by the Wright Aeronautical Corporation because it would be practically impossible to keep such a large publication up to date with current releases. However, detailed information on these releases may be obtained upon request to the Service Department. When requesting such information, give the model designation and serial number of the engine involved.

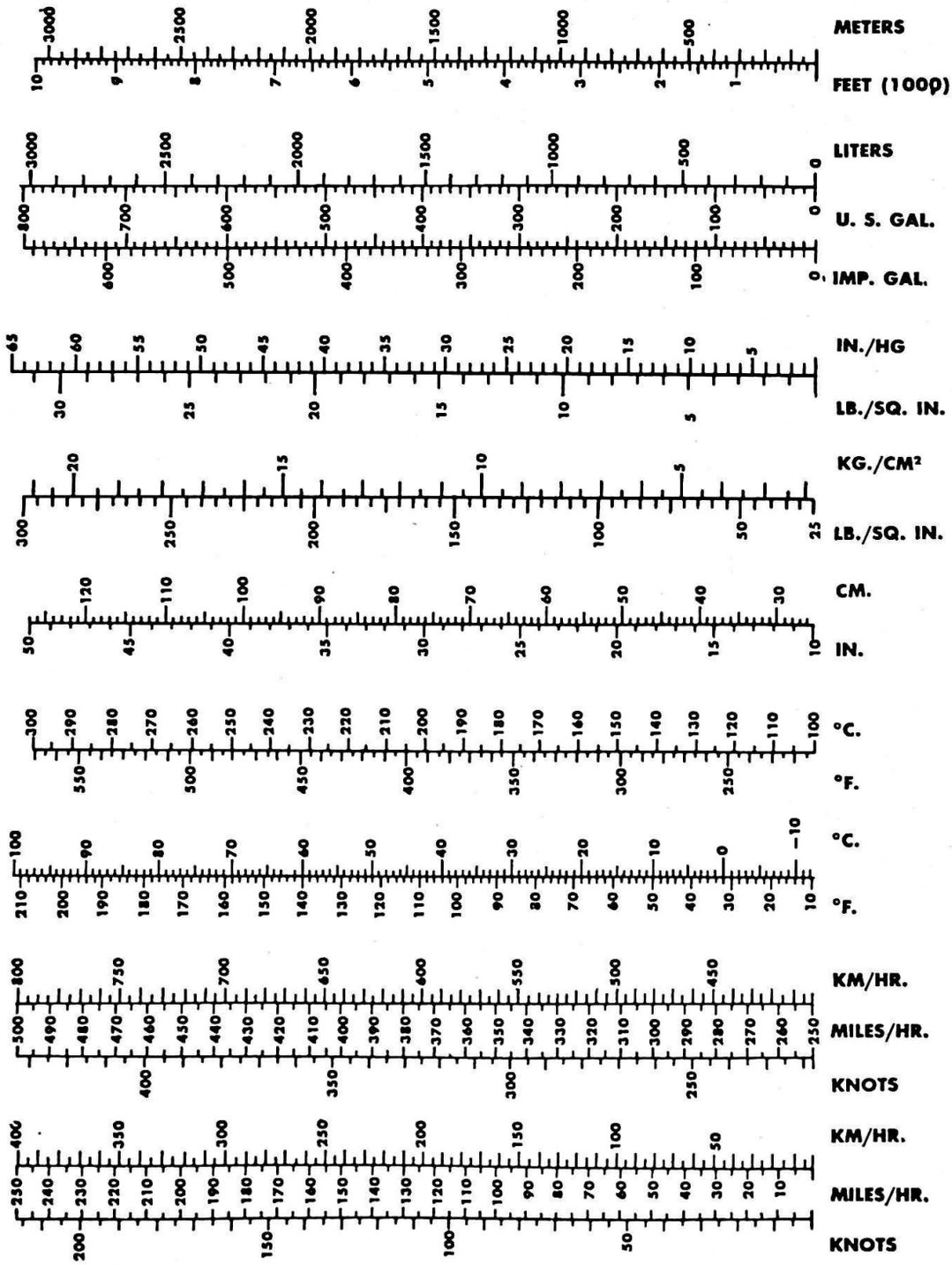
Engine materials and accessories released by the Wright Aeronautical Corporation are recommended in the interest of safe operation, and to assist the operator in obtaining the maximum performance, reliability, and service life from his engine. It is, therefore, highly recommended that operators communicate with the Service Department: whenever there is any doubt as to a release; or prior to any action concerning the installation of accessories on engines in new aircraft; prior to the installation of accessories on modernized engines; prior to the installation of additional accessories on any engine; or prior to any changes which are to be made in the materials or accessories used with any engine.

Under no conditions should any structural engine part, such as an oil pump, bearing, valve, bushing, gasket, or piston ring, which has not been procured from the Wright Aeronautical Corporation, or through its authorized agents, be used on a Cyclone 9HC engine. The use of such a part is contrary to the interests of safe engine operation and voids the engine guarantee.

APPENDIX II

TABLE OF CONVERSIONS

1 English Horsepower = 746 Watts 1.014 Metric Horsepower 1 Metric Horsepower 736 Watts



CONVERSION FACTORS

1 CM	= .394	INCHES	1 INCH	= 2.54	CM
1 METER	= 3.281	FEET	1 FOOT	= .305	METERS
1 KILOGRAM	= 2.205	POUNDS	1 POUND	= .4536	KILOGRAMS
1 SQ CM	= .155	SQ INCH	1 SQ INCH	= 6.452	SQ CM
1 KG/CM^2	= 14.22	LB/SQ INCH	1 LB/SQ INCH	= .07036	KG/CM^2
1 KM/HR	= .6241	MILE/HR	1 MILE/HR	= 1.609	KM/HR
1 KNOT	= 1.152	MILES/HR	1 MILE/HR	= .8684	KNOT
1 LITER	= .264	U.S. GAL	1 U.S. GAL	= 3.78	LITERS
1 IMPERIAL GAL	= 1.201	U.S. GAL	1 U.S. GAL	= .833	IMPERIAL GAL
1 INCH OF MERCURY	= .4912	LB/SQ INCH	1 LB/SQ INCH	= 2.036	INCHES OF MERCURY
1 INCH OF MERCURY	= 13.595	INCHES OF WATER	1 INCH OF WATER	= .0736	INCH OF MERCURY

$$F^\circ = 9/5\,(C) + 32$$

$$C^\circ = 5/9 \times (F - 32)$$

APPENDIX III

TABLE OF LIMITS

These tables are provided for use in servicing the Wright Cyclone 9HC engines. They list the maximum and minimum service clearances as recommended by the Wright Aeronautical Corporation and are to be used in conjunction with the Limits and Lubrication Charts as referred to herein.

In order to determine a particular clearance it is first necessary to locate the item number of the clearance in question on the applicable chart. The chart on which the item may be found clearly states in which Table of Limits the clearance is listed.

Maximum and Minimum clearance in both English and metric units are given in the tables opposite each reference number. The letter **L** immediately following the limit value denotes a loose or running fit, and the letter **T** denotes a tight or press fit.

TABLE OF LIMITS No. 30

Dual Accessory Drive

CYCLONE 9 ENGINES

The reference numbers listed are found on Limits and Lubrication Chart No. 26.

Reference No.	Chart No.	Description	Inches		Millimeters	
			Minimum	Maximum	Minimum	Maximum
6	26	Vacuum Pump Shaft and Accessory Drive Shaft Spline.....Side Clearance	.001L	.010L	.03L	.25L
8	26	Accessory Drive Idler Gear and Bushing .....Dia.	.002L	.008L	.05L	.20L
9	26	Accessory Drive Idler Gear..End Clearance	.006L	.040L	.15L	1.02L
10	26	Accessory Drive Idler Gear Bushing....Dia.	.001T	.003T	.03T	.08T
11	26	Accessory Drive Intermediate Gear and Intermediate Shaft Gear.....Backlash	.004	.020	.10	.51
12	26	Accessory Drive Intermediate Shaft and Bushing .....Dia.	.002L	.008L	.05L	.20L
13	26	Accessory Drive Intermediate Shaft .....End Clearance	.006L	.040L	.15L	1.02L
14	26	Accessory Drive Intermediate Shaft Bushing .....Dia.	.001T	.003T	.03T	.08T
15	26	Upper Vacuum Pump Drive Gear and Bushing .....Dia.	.002L	.008L	.05L	.20L
16	26	Upper Vacuum Pump Drive Gear .....End Clearance	.014L	.050L	.36L	1.27L

TABLE OF LIMITS No. 30 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
17	26	Upper Vacuum Pump Drive Gear Bushing .....Dia.	.001T	.003T	.03T	.08T
18	26	Accessory Drive Idler Gear and Upper and Lower Vacuum Pump Drive Gears .....Backlash	.004	.020	.10	.51
19	26	Lower Vacuum Pump Drive Gear and Front Bushing .....Dia.	.002L	.008L	.05L	.20L
20	26	Lower Vacuum Pump Drive Gear and Rear Bushing .....Dia.	.004L	.010L	.10L	.25L
21	26	Lower Vacuum Pump Drive Gear .....End Clearance	.011L	.050L	.28L	1.27L
22	26	Lower Vacuum Pump Drive Gear Front Bushing and Housing .....Dia.	.001T	.003T	.03T	.08T
23	26	Lower Vacuum Pump Drive Gear Rear Bushing and Cover .....Dia.	.002T	.004T	.05T	.10T
24	26	Upper Vacuum Pump Drive Gear Bushing (Rear) .....Dia. For involute coupling drive. (Standard and special ratio accessory drive shafts.)	.002T	.004T	.05T	.10T
25	26	Upper Vacuum Pump Drive Gear and Bushing .....Dia. For involute coupling drive. (Standard and special ratio accessory drive shafts.)	.004L	.010L	.10L	.25L
26	26	Upper Vacuum Pump Drive Gear .....End Clearance For special accessory drive shaft with a ratio of 1.636:1.	.011L	.050L	.28L	1.27L
500	26	Dual Accessory Drive Housing to Supercharger Rear Cover Attaching Nut .....Tightening Torque Threads must be lubricated with oil.	135 in.-lb	150 in.-lb	155 cm-kg	175 cm-kg
501	26	Dual Accessory Drive Housing Flange to Dual Accessory Drive Housing Cover Attaching Nut....Tightening Torque Threads must be lubricated with oil.	135 in.-lb	150 in.-lb	155 cm-kg	175 cm-kg

TABLE OF LIMITS No. 45

Tightening Torque Values

ALL MODELS

Note: Special cases and exceptions to TL-45 are listed in other Tables of Limits

STANDARD STUDS, BOLTS, SCREWS, AND CAP SCREWS

NAME	Size of Thread Nut End	Minimum Diameter of Thread Root or Neck (Inches)	Minimum Rockwell Hardness	Tightening Nut, Screw, or Cap Screw TORQUE VALUES			
				Minimum		Maximum	
				In.-Lb	Cm-Kg	In.-Lb	Cm-Kg
Button Head Screw	10-32	.1467	B-50	20	23	25	29
	12-24	.1585	B-50	25	29	30	35
Studs, Bolts, Screws, Cap Screws	10-32	.1467	C-19	35	40	40	46
	12-24	.1585	C-19	45	52	50	58
	1/4-28	.180	C-26	80	92	85	98
	5/16-24	.229	C-26	160	185	175	202
	3/8-24	.285	C-26	225	260	250	288
	7/16-20	.331	C-26	350	404	375	432
	1/2-20	.387	C-26	550	635	600	692
	9/16-18	.436	C-26	825	950	875	1008
	5/8-18	.493	C-26	1125	1297	1200	1383

STANDARD PRACTICES FOR SPECIAL APPLICATIONS

Cylinder Hold-Down Stud	3/8-24	.313	C-32	325	375	450	519
Cylinder Hold-Down Stud Nut				350	404	375	432
Cylinder Hold-Down Cap Screw	7/16-20	.330	C-26	375	432	400	461
Cylinder Hold-Down Stud	7/16-20	.331	C-32	400	461	550	635
Cylinder Hold-Down Stud Nut				425	490	450	519
Rocker Hub Bolt	7/16-20	.371	C-32	250	288	325	375
	15/32-20	.400	C-19	250	288	325	375
	9/16-18	.488	C-26	300	346	375	432
Spark Plug	18mm			300	345	360	415

TORQUE VALUES FOR DRIVING STUDS

STEPPED STUDS

TYPES X AND Y ARE DRIVEN FROM NUT END

TYPE Z IS DRIVEN FROM FLAT ON STUD END

TYPE X

TYPE Y

TYPE Z

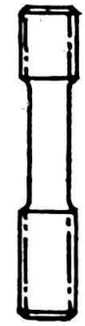
	STUD SIZE Nut End	STUD SIZE Stud End	TORQUE VALUE In.-Lb	TORQUE VALUE Cm-Kg	TORQUE VALUE In.-Lb	TORQUE VALUE Cm-Kg	TORQUE VALUE In.-Lb	TORQUE VALUE Cm-Kg
Hand Driven	.250-28	.313-18	50-100	58-115	50-70	58-81	50-110	58-127
	.313-24	.375-16	100-210	115-242	100-150	115-173	100-240	115-276
	.375-24	.438-14	200-390	230-449	200-275	230-317	200-435	230-501
	.438-20	.500-13	300-600	346-691	300-425	346-490	300-670	346-772
	.500-20	.563-12	500-980	576-1129	500-700	576-806	500-1110	576-1278
	.563-18	.625-11	750-1350	864-1555	750-975	864-1123	750-1570	864-1809
	.625-18	.688-11	1100-1950	1267-2246	1100-1400	1267-1613	1100-2130	1267-2454
Machine Driven	.250-28	.313-18	50-100	58-115	50-80	58-92	50-125	58-144
	.313-24	.375-16	100-235	115-271	100-170	115-196	100-330	115-380
	.375-24	.438-14	200-460	230-530	200-325	230-374	200-510	230-588
	.438-20	.500-13	300-730	346-841	300-520	346-599	300-820	346-945
	.500-20	.563-12	500-1130	576-1302	500-810	576-933	500-1290	576-1486
	.563-18	.625-11	750-1620	864-1866	750-1150	864-1325	750-1790	864-2062
	.625-18	.688-11	1100-2320	1267-2673	1100-1670	1267-1924	1100-2540	1267-2926

STRAIGHT STUDS

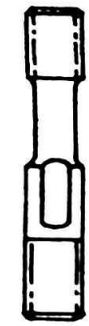
TYPES X AND Y ARE DRIVEN FROM NUT END

TYPE Z IS DRIVEN FROM FLAT ON STUD END

TYPE X



TYPE Y



TYPE Z

	STUD SIZE Nut End	STUD SIZE Stud End	TORQUE VALUE In.-Lb	TORQUE VALUE Cm-Kg	TORQUE VALUE In.-Lb	TORQUE VALUE Cm-Kg	TORQUE VALUE In.-Lb	TORQUE VALUE Cm-Kg
Hand Driven	.250-28	.250-20	50-70	58-81	50-60	58-69	50-70	58-81
	.313-24	.313-18	100-150	115-173	100-130	115-150	100-150	115-173
	.375-24	.375-16	200-275	230-317	200-230	230-265	200-275	230-317
	.438-20	.438-14	300-425	346-490	300-370	346-426	300-425	346-490
	.500-20	.500-13	500-700	576-806	400-500	461-576	500-700	576-806
	.563-18	.563-12	750-975	864-1123	500-690	576-795	750-975	864-1123
	.625-18	.625-11	1100-1400	1267-1613	700-1010	806-1164	1100-1400	1267-1613
Machine Driven	.250-28	.250-20	50-90	58-104	50-65	58-75	50-90	58-104
	.313-24	.313-18	100-200	115-230	100-165	115-190	100-200	115-230
	.375-24	.375-16	200-350	230-403	200-250	230-288	200-350	230-403
	.438-20	.438-14	300-560	346-645	300-400	346-461	300-560	346-645
	.500-20	.500-13	500-880	576-1014	400-630	461-726	500-880	576-1014
	.563-18	.563-12	750-1290	864-1486	500-920	576-1060	750-1290	864-1486
	.625-18	.625-11	1100-1790	1267-2062	700-1290	806-1486	1100-1790	1267-2062

TABLE OF LIMITS NO. 87

Two-Speed Supercharger Drive (Roller Clutch)

The reference numbers listed are found on Limits and Lubrication Chart No. 30.

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
1	30	Impeller Shaft Drive Gear and Bushing .....Dia.	.002L	.006L	.05L	.15L
2	30	Intermediate Impeller Drive Shaft and Front Bushing .....Dia.	.0015L	.006L	.038L	.15L
3	30	Impeller Shaft Drive Gear and Intermediate Drive Shaft Front Bushing .....Dia.	.0025T	.004T	.064T	.10T
4	30	Intermediate Impeller Drive Shaft and Intermediate Impeller Drive Gear Bushing .....Dia.	.0015L	.008L	.038L	.20L
5	30	Intermediate Impeller Drive Gear and Bushing .....Dia.	.0025T	.004T	.064T	.10T
6	30	Impeller Shaft Drive Gear and Intermediate Impeller Drive Pinion Cage (Front) Bushing.....Dia.	.0005L	.006L	.013L	.15L
7	30	Intermediate Impeller Drive Shaft Pinion Cage (Front) Bushing.....Dia.	.0005L	.006L	.013L	.15L
8	30	Intermediate Impeller Drive Shaft and Rear Bushing .....Dia.	.0015L	.007L	.038L	.18L
9	30	Intermediate Impeller Drive Shaft..End Play Machine at assembly. Reference No. 39, impeller drive multi-plate clutch housing and clutch roller cage clearance, is affected by this adjustment.	.020L		.51L	
10	30	Impeller Drive Multi-Plate Clutch Piston and Intermediate Impeller Drive Shaft Bushing (Rear).....Dia.	.002L	.004L	.05L	.10L
11	30	Impeller Drive Multi-Plate Clutch Piston and Oil Seal Ring..Side Clearance	.0065L	.014L	.165L	.36L
12	30	Impeller Drive Multi-Plate Clutch Piston Oil Seal Ring (Hand Fit) .....Gap	.003	.006	.08	.15
13	30	Clutch Roller Cage and Roller .....Side Clearance	.0014L	.005L	.036L	.13L
14	30	Clutch Roller Cage and Roller .....End Clearance	.0013L	.005L	.033L	.13L

TABLE OF LIMITS No. 87 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
15	30	Impeller Low Speed Drive Clutch Cam and Bushing .....Dia.	.0015T	.0035T	.038T	.089T
16	30	Intermediate Impeller Drive Shaft and Pinion .....Backlash	.004	.015	.10	.38
17	30	Intermediate Impeller Drive Gear and Generator Gear .....Backlash	.006	.020	.15	.51
18	30	Intermediate Impeller Drive Gear and Accessory Drive Gear.....Backlash	.006	.020	.15	.51
19	30	Impeller Shaft Drive Gear and Intermediate Impeller Drive Pinion .....Backlash	.006	.017	.15	.43
20	30	Impeller Shaft Drive Gear and Impeller Drive Shaft Gear.....Backlash	.003	.015	.08	.38
21	30	Intermediate Impeller Drive Shaft Pinion Cage (Front) and Pinion Shaft .....Dia.	.001L	.002L	.03L	.05L
22	30	Impeller Shaft Drive Gear and Intermediate Impeller Drive Pinion .....Backlash	.008	.020	.20	.51
23	30	Intermediate Impeller Drive Shaft and Pinion .....Backlash	.004	.015	.10	.38
24	30	Intermediate Impeller Drive Shaft Pinion Cage (Front and Rear) and Pinion Bushing .....Dia.	.0005L	.006L	.013L	.15L
25	30	Intermediate Impeller Drive Pinion and Bushing (Front and Rear).....Dia.	.0005L	.006L	.013L	.15L
26	30	Impeller Drive Multiplate Clutch Piston and Two-Speed Clutch Thrust Washer Lock.....Dia.	.002T	.0045T	.05T	.114T
27	30	Impeller Drive Multiplate Clutch Sleeve and Supercharger Rear Cover .....Dia.	.000	.003T	.00	.08T
28	30	Impeller Drive Multiplate Clutch Housing and Sleeve .....Dia.	.003L	.010L	.08L	.25L
29	30	Supercharger Clutch Oil Control Valve and Sleeve.....Dia.	.0005L	.0025L	.013L	.064L
30	30	Supercharger Clutch Oil Control Valve Sleeve and Supercharger Rear Cover .....Dia.	.0005T	.001L	.013T	.03L

TABLE OF LIMITS No. 87 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
31	30	Supercharger Clutch Oil Control Valve Spring Wire Diameter .055 in. (1.40mm) Load at .960 in. (24.38mm) Height.....	5 lb		2.27 kg	
32	30	Impeller Clutch Release Spring Wire Diameter .093 in. (2.36mm) Load at .750 in. (19.05mm) Height.....	18 lb		8.16 kg	
33	30	Impeller Intermediate Drive Pinion Shaft and Pinion Bushing.....Dia.	.0005L	.006L	.013L	.15L
34	30	Intermediate Impeller Drive Pinion and Bushing .....Dia.	.0005L	.006L	.013L	.15L
35	30	Intermediate Impeller Drive Shaft Pinion Cage (Rear) and Pinion Shaft .....Dia.	.001T	.0025T	.03T	.064T
36	30	Intermediate Impeller Drive Pinion and Bushing .....Side Clearance	.004L	.020L	.10L	.51L
37	30	Impeller Drive Shaft Gear....End Clearance	.012L	.017L	.30L	.43L
38	30	Accessory Drive and Starter Shaft (Machine at Assembly)....End Clearance	.020L	.040L	.51L	1.02L
39	30	Impeller Drive Multi-Clutch Housing and Clutch Roller Cage .....Clearance Adjust intermediate impeller drive shaft end play, Reference No. 9, to obtain this clearance.	.030L		.76L	

TABLE OF LIMITS No. 101

Longitudinal Section and Section Through Accessory Drives

CYCLONE 9HC ENGINE BASIC

The reference numbers listed are found on Limits and Lubrication Charts No. 31 and 32.

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
1	31	Propeller Shaft .....End Play	.0056	.025	.142	.64
2	31	Allowable Run-out of Propeller Shaft..... Between threads and splines at forward end when in position in engine.	.012	Maximum Full Indicator Reading	.30	Maximum Full Indicator Reading
3	31	Spline .....Side Clearance Movement of propeller hub on propeller shaft measured at 15 inch (381mm) radius from center of propeller shaft.	.040		1.02	
4	31	Propeller Shaft.....Total Radial Looseness To be measured 1 inch (25.4mm) from thrust bearing nut with engine hot. To secure accurate measurement an indicator must be used.		.015		.38
5	31	Propeller Shaft .....Length Thrust nut to center of hole.	8.547	8.577	217.09	217.86
6	31	Oil Pump Body and Oil Sump Scavenge Pump Gears .....Dia.	.004L	.010L	.10L	.25L
7	31	Oil Pump Body Cover and Oil Scavenge Pump Driven Gear .....Dia.	.002L	.005L	.05L	.13L
8	31	Oil Pump Body Cover and Oil Scavenge Pump Drive Gear .....Dia.	.002L	.005L	.05L	.13L
9	31	Oil Sump Scavenge Pump Gears.....End	.0025L	.0085L	.064L	.216L
10	31	Oil Sump Scavenge Pump Drive Shaft Gear and Bushing.....Dia.	.002L	.005L	.05L	.13L
11	31	Oil Pump Body and Oil Sump Scavenge Pump Drive Shaft Gear Bushing.....Dia	.0005T	.0025T	.013T	.064T
12	31	Oil Pump Body and Oil Sump Scavenge Pump Driven Gear	.002L	.005L	.05L	.13L
13	31	Oil Sump Scavenge Pump Drive and Driven Gears .....Backlash	.002	.014	.05	.36
14	31	Crankshaft Front End and Propeller Shaft Front Bushing.....Dia.	.0025L	.006L	.064L	.15L
15	31	Propeller Shaft Sleeve and Bushing.....Dia.	.0015T	.0035T	.038T	.089T
16	31	Propeller Shaft Sleeve and Propeller Shaft .....Dia.	.0015T	.0045T	.038T	.114T

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
17	31	Propeller Shaft Thrust Bearing Spacer Oil Seal Ring (Hand Fit).....Gap	.012	.013	.30	.33
18	31	Propeller Shaft Thrust Bearing Nut Oil Seal Ring (Hand Fit).....Gap	.003	.015	.08	.38
19	31	Propeller Shaft Thrust Bearing Nut Oil Seal Ring .....Side	.003L	.015L	.08L	.38L
20	31	Propeller Shaft Thrust Bearing .....End Movement	.0056	.0191	.142	.485
21	31	Stationary Reduction Gear Support and Sleeve .....Dia.	.005T	.007T	.13T	.18T
22	31	Propeller Shaft Thrust Bearing Retainer and Crankcase Front Section.....Dia.	.004T	.008T	.10T	.20T
23	31	Propeller Shaft Thrust Bearing Retainer and Bearing .....Dia.	.0004L	.0030L	.010L	.076L
23A	31	Propeller Shaft Thrust Bearing Retainer and Bearing—Select to Obtain.....Dia. For B-17 installation only.	.0005T	.0005L	.013T	.013L
24	31	Propeller Shaft and Thrust Bearing Spacer .....Dia.	.001L	.001T	.03L	.03T
25	31	Reduction Gear Pinion and Bushing....Side	.003L	.010L	.08L	.25L
26	31	Reduction Gear Pinion and Bushing.....Dia.	.0013L	.0035L	.033L	.089L
27	31	Reduction Gear Pinion Bushing and Carrier .....Dia.				
		Front End	.0005L	.006L	.013L	.15L
		Rear End	.0015L	.006L	.038L	.15L
28	31	Reduction Gear Pinion and Stationary Reduction Gear .....Backlash	.011	.027	.28	.69
29	31	Crankshaft Oil Seal Ring (Hand Fit).....Gap	.018	.020	.46	.51
30	31	Oil Sump Scavenge Pump Drive Shaft Gear and Bushing.....Dia.	.001L	.005L	.03L	.13L
31	31	Oil Sump Scavenge Pump Drive Shaft Gear Support and Bushing.....Dia.	.0015T	.0035T	.038T	.089T
32	31	Reduction Gear Pinion Carrier and Propeller Shaft .....Dia.	.001T	.001L	.03T	.03L
33	31	Oil Sump Scavenge Pump Driven Coupling Gear and Drive Shaft Gear .....Backlash	.004	.020	.10	.51
34	31	Oil Sump Scavenge Pump Driven Coupling Gear and Bushing.....End	.002L	.010L	.05L	.25L

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
35	31	Crankcase Main Section and Crankcase Front Section .....Dia.	.002T	.006L	.05T	.15L
36	31	Oil Sump Scavenge Pump Driven Coupling Gear and Bushing.....Dia.	.001L	.005L	.03L	.13L
37	31	Cam Support and Bushing.....Dia.	.0015T	.0035T	.038T	.089T
38	31	Crankcase Main Section and Cam Support .....Dia.	.0005T	.0025T	.013T	.064T
39	31	Oil Sump Scavenge Pump Driven Coupling Gear Pinion and Cam.....Backlash	.008	.024	.20	.61
40	31	Crankcase Front Main Bearing Ring and Crankcase .....Dia.	.001T	.002L	.03T	.05L
41	31	Crankcase Front Main Bearing Ring and Bearing .....Dia.	.002L	.006L	.05L	.15L
41A	31	Crankcase Front Main Bearing Ring and Bearing—Select to Obtain.....Dia. For B-17 installation only.	.0005T	.0005L	.013T	.013L
42	31	Front Counterweight Crankshaft Bushing and Crankshaft .....Dia.	.001T	.0025T	.03T	.064T
43	31	Front Counterweight and Stop	.0325L	.050L	.826L	1.27L
44	31	Front Counterweight and Bushing.....Dia.	.0015T	.003T	.038T	.08T
45	31	Crankshaft Plug and Crankshaft.....Dia.	.001T	.003L	.03T	.08L
46	31	Crankpin Plug and Crankpin.....Dia.	.0005L	.002L	.013L	.05L
47	31	Master Rod and Knuckle Pin.....Dia.	.0005L	.002L	.013L	.05L
48	31	Articulated Rod and Knuckle Pin Bushing .....Dia.	.0045T	.0065T	.114T	.165T
49	31	Crankshaft Rear End and Counterweight Bearing .....Dia.	.001T	.0025T	.03T	.064T
50	31	Rear Counterweight and Bushing.....Dia.	.0015T	.003T	.038T	.08T
51	31	Counterweight Rear Crankshaft Bearing and Bushing—Select to Obtain....Dia.	.0025L	.0035L	.064L	.089L
52	31	Knuckle Pin and Bushing.....Dia.	.0027L	.006L	.069L	.15L
53	31	Rear Counterweight and Stop.....	.0245L	.030L	.622L	.76L
54	31	Master Rod and Knuckle Pin Bushing .....Side	.007L	.030L	.18L	.76L
55	31	Crankcase Main Rear Bearing Ring and Crankcase .....Dia.	.004T	.006T	.10T	.15T
56A	31	Crankcase Main Rear Bearing Ring and Bearing .....Dia.	.004L	.008L	.10L	.20L

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
56	31	Crankcase Rear Main Bearing Ring and Bearing—Select to Obtain.....Dia. For B-17 installation only.	.0005T	.0005L	.013T	.013L
57	31	Crankshaft .....End Play	.014L	.051L	.36L	1.30L
58	31	Crankshaft Rear Bearing and Crankshaft .....Dia.	.001T	.0024T	.03T	.061T
59	31	Impeller Shaft Oil Seal Sleeve and Ring (Front) .....Side	.005L	.009L	.13L	.23L
60	31	Supercharger Rear Housing and Intermediate Impeller Drive Shaft Bushings .....Dia.	.001T	.0045T	.03T	.114T
61	31	Generator Drive Gear .....End	.007L	.045L	.18L	1.14L
62	31	Intermediate Impeller Drive Shaft and Front Bushing .....Dia.	.0005L	.004L	.013L	.10L
63	31	Impeller Shaft Oil Seal Sleeve and Ring (Rear) .....Side	.005L	.009L	.13L	.23L
64	31	Generator Drive Gear and Intermediate Drive Gear .....Backlash	.004	.020	.10	.51
65	31	Generator Drive Gear and Bushing.....Dia.	.001L	.008L	.03L	.20L
66	31	Generator Gear Shaft Bushing and Supercharger Rear Cover.....Dia.	.0015T	.0035T	.038T	.089T
67	31	Supercharger Rear Housing and Sleeve .....Dia.	.001T	.003T	.03T	.08T
68	31	Impeller Drive Pinion and Accessory Drive Gear .....Backlash	.006	.025	.15	.64
69	31	Starter Coupling.....Locating Dimension After obtaining clearane per Reference No. 76 machine "Spacer R" to obtain this dimension with the starter coupling located in extreme "in" position (forward against accessory shaft with accessory shaft resting against forward thrust ring).	1.714	1.719	43.54	43.66
70	31	Intermediate Impeller Drive Shaft .....End Play	.023L	.057L	.58L	1.45L
71	31	Impeller Shaft .....End Adjust at assembly.	.012L	.017L	.31L	.43L
72	31	Impeller Shaft Gear and Drive Gear .....Backlash	.004	.018	.10	.46
73	31	Intermediate Impeller Drive Shaft and Rear Bushing .....Dia.	.0005L	.005L	.013L	.13L

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
74	31	Supercharger Rear Cover and Intermediate Impeller Drive Shaft Rear Bushing .....Dia.	.001T	.003T	.03T	.08T
75	31	Accessory Drive and Starter Shaft and Impeller Shaft Rear Bushing.....Dia.	.002L	.006L	.05L	.15L
76	31	Accessory Drive and Starter Shaft.....Side Machine in assembly.	.020L	.040L	.51L	1.02L
77	31	Starter Coupling Spacer and Starter Shaft Oil Retaining Plug.....Dia.	.002L	.005L	.05L	.13L
78	31	Starter Coupling Spring Wire Diameter .125 in. (3.18mm) Load at .890 in. (22.61mm) Height.....	52.2 lb	63.8 lb	23.68 kg	28.94 kg
79	31	Accessory Drive and Starter Shaft and Oil Retaining Plug .....Dia.	.000	.0015T	.00	.038T
80	31	Accessory Drive and Starter Shaft and Rear Bushing .....Dia.	.002L	.005L	.05L	.13L
81	31	Impeller Shaft Retainer Oil Seal Ring (Hand Fit) .....Gap	.006	.008	.15	.20
82	31	Accessory Drive and Starter Shaft Bushing and Supercharger Rear Cover....Dia.	.005T	.007T	.13T	.18T
83	31	Impeller Shaft Retainer and Oil Seal Ring .....Side	.002L	.011L	.05L	.28L
84	31	Impeller Shaft and Rear Bushing.....Dia.	.002T	.004T	.05T	.10T
85	31	Impeller Shaft and Rear Oil Seal Sleeve .....Dia.	.000	.004L	.00	.10L
86	31	Impeller Oil Seal Ring Front and Rear (Hand Fit) .....Gap	.010	.012	.25	.31
87	31	Impeller and Shaft.....	Impeller Must Be a Tight Fit on Splines			
88	31	Accessory Drive and Starter Shaft and Impeller Shaft Front Bushing.....Dia.	.0025L	.006L	.064L	.15L
89	31	Impeller Shaft and Front Bushing.....Dia.	.002T	.004T	.05T	.10T
90	31	Impeller Shaft and Oil Seal Front Sleeve .....Dia.	.000	.004L	.00	.10L
91	31	Supercharger Front and Rear Housings .....Dia.	.002T	.006L	.05T	.15L
92	31	Starter Shaft and Coupling Ring.....Gap	.0006	.004	.015	.10
93	31	Impeller and Front Supercharger Housing .....Side	.030L		.76L	

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
94	31	Impeller and Diffuser Plate .....Side This clearance to be maintained at all points of impeller circumference.	.035L	.045L	.89L	1.14L
95	31	Accessory Drive and Starter Shaft and Oil Seal Ring .....Side	.002L	.008L	.05L	.20L
96	31	Accessory Drive and Starter Shaft Coupling and Crankshaft.....Dia. Select to obtain.	.001T	.002T	.03T	.05T
97	31	Diffuser Plate Vanes and Supercharger Front Housing	.005T	.012T	.13T	.31T
98	31	Supercharger Front Housing Breather Relief Valve Spring Wire Diameter .030 in. (.76mm) Load at .500 in. (12.7mm) Height.....	.35 lb	.56 lb	.159 kg	.254 kg
99	31	Crankcheek Cap Screw.....Stretch	.008	.010	.20	.25
100	31	Crankpin Bearing .....End Clearance End clearance to be measured with master rod in extreme forward position.	.018L	.055L	.46L	1.40L
101	31	Master Rod and Master Rod Spacer.....Dia.	.001L	.008L	.03L	.20L
102	31	Crankpin Bearing and Crankpin .....Dia. Loose prefit bearing.	.004L	.0065L	.10L	.165L
103	31	Master Rod and Bearing .....Dia. Loose prefit bearing.	.001L	.0035L	.03L	.089L
104	31	Master Rod and Knuckle Pin Locking Plate .....Dia.	.0005T	.0015L	.013T	.038L
105	31	Master Rod Oil Seal Disk Spring— Load When Compressed to .320 in. (8.13mm) Height	6 lb	10 lb	2.7 kg	4.5 kg
106	31	Knuckle Pin Locking Plate and Master Rod Oil Seal Disk .....Dia.	.0005L	.005L	.013L	.13L
107	31	Master Rod Oil Seal Disk Lugs and Knuckle Pin Locking Plate Lugs.....Side	.005L	.030L	.13L	.76L
108	31	Piston Groove No. 6 and Ring.....Side	.006L	.008L	.15L	.20L
108A	31	Piston Groove No. 5 and Ring.....Side	.011L	.013L	.28L	.33L
109	31	Piston Groove (Top) No. 1 and Ring (Wedge) .....Side	.003L	.007L	.08L	.18L
109A	31	Piston Grooves No. 2 and No. 3 and Ring (Wedge) .....Side	.005L	.009L	.13L	.23L
110	31	Piston Groove No. 4 and Rings.....Side	.0065L	.009L	.165L	.23L
111	31	Piston Pin and Piston.....Dia.	.000	.004L	.00	.10L
112	31	Piston Pin Plug and Piston Pin.....Dia.	.001L	.004L	.03L	.10L

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
112A	31	Piston Pin Plug and Cylinder Barrel (Total) .....Side Clearance	.009L	.035L	.23L	.89L
113	31	Piston Ring—Groove No. 1 (Top).....Gap	.069		1.75	
113A	31	Piston Ring—Grooves No. 2, 3, 5, and 6 .....Gap	.044		1.12	
113B	31	Piston Ring—Groove No. 4.....Gap Ring gaps must be on piston pin side. Stagger gaps about 1-1/2 in. apart with gaps of 1st and 3rd rings in line.	.043		1.09	
114	31	Piston and Cylinder Barrel .....Dia. Center of skirt.	.023L	.041L	.58L	1.04L
114A	31	Piston Wear .....Dia. Center of skirt.		.004		.10
115	31	Cylinder Barrel Bore.....Taper		.010		.25
	31	Cylinder Barrel Bore.....Wear		.010		.25
	31	Cylinder Barrel .....Out-of-Round		.005		.13
116	31	Piston Pin Bushing and Piston Pin.....Dia.	.002L	.008L	.05L	.20L
117	31	Piston Pin Bushing and Connecting Rod .....Dia.	.0045T	.0065T	.114T	.165T
118	31	Cam and Cam Drive Pinion .....Backlash	.008	.024	.20	.61
119	31	Cam Drive Gear and Pinion (Spline Fit).....	.001T	.010L	.03T	.25L
120	31	Valve Tappet Spring Wire Diameter .063 in. (1.600mm) Load at 2.14 in. (54.356mm) Height.....	9.5 lb	12 lb	4.3 kg	5.44 kg
121	31	Valve Tappet and Ball Socket.....Dia.	.0012L	.0030L	.038L	.076L
122	31	Valve Tappet and Guide.....Dia.	.00175L	.00425L	.0444L	.1079L
123	31	Valve Tappet Guide and Crankcase Front Section .....Dia.	.000	.002L	.00	.05L
124	31	Valve Tappet Roller and Bushing.....Dia.	.001L	.005L	.03L	.13L
125	31	Valve Tappet and Valve Tappet Roller..Side	.0075L	.015L	.181L	.38L
126	31	Valve Tappet and Valve Tappet Roller Bushing .....Side	.007L	.015L	.18L	.38L
127	31	Valve Tappet Roller Pin and Guide.....Side	.005L	.016L	.13L	.41L
128	31	Valve Tappet Roller Pin and Bushing and Valve Tappet .....Dia.	.0025L	.006L	.064L	.15L
129	31	Cam and Cam Ring.....Dia.	.010L	.015L	.25L	.38L
130	31	Governor Drive Gear and Intermediate Drive Gear .....Backlash	.004	.020	.10	.51
131	31	Cam and Oil Sump Pump Drive and Ring .....Dia.	.001T	.005T	.03T	.13T

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
132	31	Cam and Cam Guide.....Side	.006L	.012L	.15L	.31L
133	31	Governor Drive Gear Shaft and Bushing .....Dia.	.002L	.006L	.05L	.15L
134	31	Governor Drive Shaft Bushing and Crankcase .....Dia.	.001T	.003T	.03T	.08T
135	31	Cam Intermediate Drive Gear and Bushing and Cam Drive Pinion.....End	.002L	.015L	.05L	.38L
136	31	Governor Drive Gear Shaft and Plug....Dia.	.002T	.023T	.05T	.58T
137	31	Cam Drive Intermediate Gear and Bushing .....Dia.	.0015L	.0055L	.038L	.140L
138	31	Reduction Drive Gear and Pinion..Backlash	.011	.027	.28	.69
139	31	Cam Support and Cam Drive Gear Bushing .....Dia.	.0015T	.0035T	.038T	.089T
140	31	Bearing and Crankshaft Front End.....Dia.	.0002T	.0016T	.005T	.040T
141	31	Crankshaft Oil Seal Ring and Spacer..Side	.001L	.012L	.03L	.31L
142	31	Reduction Driving Gear and Cam Drive Intermediate Gear .....Backlash	.004	.020	.10	.51
143	31	Crankshaft Front End and Oil Seal Ring Spacer .....Dia.	.0005L	.005L	.013L	.13L
144	31	Crankshaft Front End and Propeller Shaft Rear Bushing .....Dia.	.003L	.007L	.08L	.18L
145	31	Propeller Shaft Thrust Bearing and Retainer .....Side	.0001T	.0059L	.003T	.150L
146	31	Propeller Shaft Thrust Bearing Spacer and Ring .....Side	.001L	.010L	.03L	.25L
147	31	Propeller Shaft and Sleeve.....Dia.	.0015T	.0045T	.038T	.114T
148	31	Propeller Shaft Thrust Bearing Spacer and Propeller Shaft—Select to Obtain .....Dia.	.001T	.001L	.03T	.03L
149	31	Propeller Shaft and Thrust Bearing.....Dia.	.0002T	.0016T	.005T	.040T
150	31	Propeller Shaft and Rear Bushing.....Dia.	.0025T	.0045T	.064T	.114T
151	32	Pump Drive Gear Bushing and Supercharger Rear Cover .....Dia.	.001T	.0035T	.03T	.089T
152	32	Oil Pump Drive Shaft and Oil Pump End Plate .....Dia.	.002L	.015L	.05L	.38L
153	32	Oil Pump Drive Shaft and Body.....End	.0065L	.015L	.165L	.38L
154	32	Oil Pump Idler Gear Shaft and Pump End Plate .....Dia.	.0005T	.002L	.013T	.05L
155	32	Oil Suction Pump Idler Gear and Body..End	.0065L	.015L	.165L	.38L

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
156	32	Oil Pump Drive Shaft and Oil Suction Pump Idler Gear .....Backlash		.014		.36
157	32	Oil Suction Pump Idler Gear Shaft and Oil Suction Pump Idler Gear.....Dia.	.0015L	.008L	.038L	.20L
158	32	Oil Pump Drive Shaft and Oil Pressure Pump Drive Gear .....Dia.	.0005L	.002L	.013L	.05L
159	32	Oil Suction Pump Idler Gear Shaft and Body (Hole) .....Dia.	.001T	.0025T	.03T	.064T
160	32	Oil Pressure Pump Drive Gear and Body .....Dia.	.005L	.009L	.13L	.23L
161	32	Oil Pressure Pump Drive Gear and Oil Pump Cover .....Dia.	.002L	.010L	.05L	.25L
162	32	Tachometer Drive Gear Shaft and Oil Pressure Pump Drive Gear.....Dia.	.0005L	.002L	.013L	.05L
163	32	Tachometer Drive Oil Seal Thrust Spring Retainer and Bushing .....Dia.	.003L	.008L	.08L	.20L
164	32	Tachometer Drive Gear Shaft and Tachometer Drive Shaft.....Backlash	.004	.020	.10	.51
165	32	Tachometer Drive Gear Shaft and Tachometer Drive Oil Seal Thrust Spring Retainer .....Dia.	.003L	.008L	.08L	.20L
166	32	Tachometer Drive Shaft Housing and Tachometer Drive Shaft Housing Cover .....Dia.	.0005T	.0035L	.013T	.089L
167	32	Tachometer Drive Shaft Housing and Bushing .....Dia.	.0015T	.0035T	.013T	.089T
168	32	Tachometer Drive Shaft Sleeve and Bushing .....Dia.	.003L	.006L	.08L	.15L
169	32	Tachometer Drive Shaft and Sleeve.....Dia. Shoulder End	.0005T	.0035T	.013T	.089T
		Outer End	.0015L	.0035T	.038L	.089T
170	32	Tachometer Drive Oil Seal Thrust Spring Wire Diameter .048 in. (1.219mm) Load at .500 in. (12.7mm) Height.....	4.50 lb	5.50 lb	2.041 kg	2.494 kg
171	32	Tachometer Drive Gear Shaft and Tachometer Drive Shaft.....Backlash	.004	.020	.10	.51
172	32	Tachometer Drive Bushing ID Anti-Propeller End and Tachometer Drive Shaft .....Dia.	.002L	.005L	.05L	.13L

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
173	32	Tachometer Drive Shaft Bushing and Tachometer Drive Housing Cover.....Dia.	.001T	.003T	.03T	.08T
174	32	Tachometer Drive Shafts and Oil Seal Thrust Spring Bushings .....Dia.	.001T	.0025T	.03T	.064T
175	32	Tachometer Drive Bushing ID Propeller End and Tachometer Drive Shaft .....Dia.	.002L	.005L	.05L	.13L
176	32	Oil Pump Cover and Tachometer Drive Bushing OD Propeller End.....Dia.	.001T	.003T	.03T	.08T
177	32	Oil Pressure Pump Idler Gear and Oil Pump Cover (Hole)	.002L	.010L	.05L	.25L
178	32	Oil Pressure Relief Valve Spring Wire Diameter .063 in. (1.60mm) Load at 1.380 in. (35.05mm) Height.....	6 lb	8 lb	2.7 kg	3.6 kg
179	32	Oil Pressure Pump Idler Gear and Body .....End	.0055L	.014L	.140L	.36L
180	32	Oil Pump Check Valve Spring Wire Diameter .047 in. (1.19mm) Load at 2 in. (50.8mm) Height.....	3.50 lb	4.00 lb	1.588 kg	1.814 kg
181	32	Oil Pump Check Valve Body and Pump Body .....Dia.	.001T	.0025T	.03T	.064T
182	32	Oil Pump Check Valve Body and Oil Pump Check Valve .....Dia.	.020L	.036L	.51L	.91L
183	32	Oil Pressure Pump Drive Gear and Body .....End	.0055L	.0095L	.140L	.241L
184	32	Oil Pump Check Valve and Oil Pump Check Valve Oil Seal Ring.....Side	.002L	.006L	.05L	.15L
185	32	Oil Pump Check Valve Oil Seal Ring....Gap	.0054	.0126	.137	.320
186	32	Oil Pressure Pump Idler Gear and Oil Pressure Pump Drive Gear.....Backlash		.020		.51
187	32	Oil Pressure Pump Idler Gear and Body (Hole) .....Dia.	.002L	.010L	.05L	.25L
188	32	Oil Pump Drive Shaft and Oil Suction Pump Idler Gear and Body.....Dia.	.005L	.009L	.13L	.23L
189	32	Pump Drive Gear and Bushing.....Dia.	.001L	.008L	.03L	.20L
190	32	Oil Pump Drive Gear Spring Wire Diameter .071 in. (1.80mm) Load at 1.78 in. (45.2mm) Height.....	8 lb	10 lb	3.6 kg	4.5 kg
191	32	Pump Drive Gear.....End	.028L	.060L	.71L	1.52L
192	32	Pump Drive Gear and Plug.....Dia.	.0005T	.0035T	.013T	.089T

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximu
193	32	Oil Pressure Pump Idler Gear and Body .....Dia.	.004L	.010L	.10L	.25L
194	32	Fuel Pump Drive Shaft Thrust Button and Supercharger Rear Cover .....Dia.	.001T	.003T	.03T	.08T
195	32	Fuel Pump Drive Shaft and Plug.....Dia.	.0005T	.002T	.013T	.05T
196	32	Fuel Pump Drive Shaft.....End	.011L	.040L	.28L	1.02L
197	32	Fuel Pump Drive Shaft Support and Supercharger Rear Cover .....Dia.	.000	.004L	.00	.10L
198	32	Fuel Pump Drive Shaft Support and Bushing .....Dia.	.001T	.003T	.03T	.08T
199	32	Fuel Pump, Tachometer, and Dual Accessory Drive Gear Shaft and Bushing..Dia.	.001L	.008L	.03L	.20L
200	32	Fuel Pump, Tachometer, and Dual Accessory Drive Gear Shaft and Supercharger Rear Cover .....Dia.	.001T	.003T	.03T	.08T
201	32	Fuel Pump, Tachometer, and Dual Accessory Drive Shaft and Plug.....Dia.	.0005T	.0035T	.013T	.089T
202	32	Fuel Pump, Tachometer, and Spare Drive Shaft .....End	.015L	.039L	.38L	.99L
203	32	Magneto Drive Gear and Pump Drive Gear .....Backlash	.004	.012	.10	.31
204	32	Magneto Drive Shaft .....End	.000	.032L	.00	.81L
205	32	Magneto and Gun Synchronizer Drive Shaft and Plug .....Dia.	.0005T	.0035T	.013T	.089T
206	32	Magneto Drive Shaft and Bushing.....Dia.	.001L	.008L	.03L	.20L
207	32	Magneto Drive Shaft Bushing and Supercharger Rear Cover .....Dia.	.001T	.003T	.03T	.08T
208	32	Fuel Pump Drive Shaft and Bushing.....Dia.	.001L	.008L	.03L	.20L
209	32	Accessory Drive Gear and Accessory Gear .....Backlash	.004	.020	.10	.51
210	32	Accessory Drive Gear Spring Wire Diameter .225 in. (5.72mm) Load at 1.544 in. (39.22mm) Height.....	530 lb	625 lb	240 kg	284 kg
211	32	Gun Synchronizer Drive Shaft Thrust Button and Supercharger Rear Cover .....Dia.	.001T	.003T	.03T	.08T
212	32	Pump Drive Gear and Accessory Drive Gear .....Backlash	.004	.020	.10	.51
213	32	Pump Drive Gear and Magneto Drive Gear .....Backlash	.004	.012	.10	.31

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
214	32	Oil Strainer Relief Valve Spring Wire Diameter .0345 in. (.875mm) Load at 1.200 (30.48mm) Height.....	1.82 lb	2.32 lb	.83 kg	1.05 kg
215	32	Oil Strainer Pilot Extension and Supercharger Rear Cover .....Dia.	.000	.005L	.00	.13L
216	32	Intake Valve Guide and Cylinder Head .....Dia.	.001T	.003T	.03T	.08T
217	32	Intake Valve and Valve Guide.....Dia. Center	.002L	.008L	.05L	.20L
		Ends	.002L	.010L	.05L	.25L
218	32	Exhaust Valve and Valve Guide.....Dia. Center	.0035L	.008L	.089L	.20L
		Ends	.0035L	.010L	.089L	.25L
219	32	Exhaust Valve Guide and Cylinder Head .....Dia.	.001T	.003T	.03T	.08T
220	32	Valve Spring (Outer) Wire Diameter .244 in. (6.20mm) Load at 1.406 in. (35.71mm) Height.....	198 lb		89.8 kg	
		Valve Spring (Inner) Wire Diameter .188 in. (4.78mm) Load at 1.561 in. (39.65mm) Height.....	112 lb		50.8 kg	
221	32	Exhaust Valve Oil Seal Ring Spacer and Retainer .....Dia.	.0008L	.0012T	.020L	.030T
222	32	Exhaust Valve Spacer Retainer and Guide .....Dia.	.0005L	.003L	.013L	.08L
223	32	Rocker Roller Hub and Pin.....Dia.	.001T	.002L	.03T	.05L
224	32	Rocker Hub Bolt and Bushing.....Dia.	.0005L	.005L	.013L	.13L
225	32	Rocker Arm Bearing and Rocker Bolt....Dia.	.000	.004L	.00	.10L
226	32	Rocker Arm Bearing and Rocker.....Dia.	.000	.0018T	.00	.046T
227	32	Rocker Hub Bolt Bushing and Bearing..Side	.0005T	.010L	.013T	.25L
228	32	Rocker Hub Bolt Bushing and Cylinder Head .....Dia.	.0015T	.003T	.038T	.08T
229	32	Rocker Roller and Rocker Arm.....Side	.0095L	.050L	.241L	1.27L
230	32	Rocker Roller Hub and Rocker Arm.....Side	Rivet Tight		Rivet Tight	
231	32	Rocker Roller Hub and Rocker Roller....Dia.	.0015L	.020L	.038L	.51L
232	32	Valve Clearance	.010		.25	
		If this clearance aligns oil hole in adjusting screw with split in rocker arm, turn screw in direction to increase valve clearance until hole is closed off .090 in. (2.29mm) or until .017 in. (.43mm) valve clearance is obtained, whichever occurs first. In no case must .017 in. (.43mm) clearance be exceeded.				

TABLE OF LIMITS No. 101 (Continued)

Reference No.	Chart No.	Description	Inches Minimum	Inches Maximum	Millimeters Minimum	Millimeters Maximum
233	31	Crankshaft and Crankshaft Breather Support (Rear) .....Dia.	.001T	.003L	.03T	.08L
234	31	Crankshaft and Crankshaft Breather Support (Front) .....Dia.	.001L	.003L	.03L	.08L
235	31	Crankshaft Breather Support and Crankshaft Breather Tube .....Dia.	.0005L	.0025L	.013L	.064L
236	31	Reduction Gear Pinion Bushing and Propeller Shaft Arm (Shrink Fit).....Dia.	.002T	.004T	.05T	.10T
237	31	Reduction Gear Drive Pinion and Bushing .....Dia.	.002L	.006L	.05L	.15L
238	31	Reduction Gear Drive Pinion and Propeller Shaft Arm .....Side	.006L	.025L	.15L	.64L
239	31	Stationary Reduction Gear and Pinion .....Backlash	.006	.020	.15	.51
240	31	Reduction Driving Gear and Pinion .....Backlash	.008	.022	.20	.56
500	31	Propeller Shaft Hydro Oil Connection Cover Nut .....Tightening Torque Use Lubriplate on threads.	2000 in. lb	2200 in. lb	2304 cm-kg	2534 cm-kg
501	31	Crankcase Front Cover Attaching Nut and Screw, also Stationary Reduction Gear Attaching Stud Nut .....Tightening Torque Threads must be lubricated with oil.	300 in. lb	350 in. lb	346 cm-kg	403 cm-kg
502	31	Carrier Ring to Propeller Shaft Attaching Bolt .....Tightening Torque Threads must be lubricated with oil.	750 in. lb	850 in. lb	864 cm-kg	979 cm-kg
503	31	Impeller Drive Shaft Gear Nut .....Tightening Torque Threads must be lubricated with oil.	3750 in. lb	4250 in. lb	4320 cm-kg	4896 cm-kg
504	31	Reduction Gear Drive Pinion Lock Nut .....Tightening Torque Threads must be lubricated with oil.	350 in. lb	400 in. lb	532 cm-kg	608 cm-kg

WRIGHT CYCLONE ENGINES

SERIES 9HC

LIMITS AND LUBRICATION CHART

WRIGHT CYCLONE ENGINES

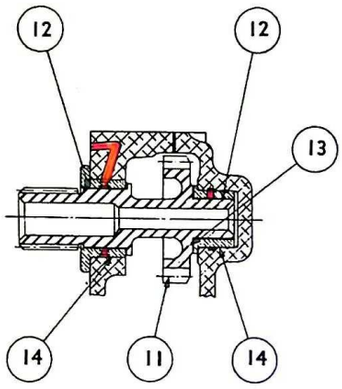
SERIES 9HC

LIMITS AND LUBRICATION CHART

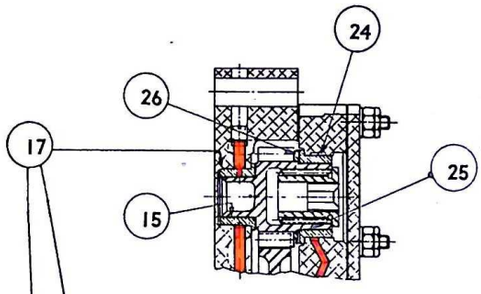
CHART NO. 26

DUAL ACCESSORY DRIVE
FOR USE WITH TL-30

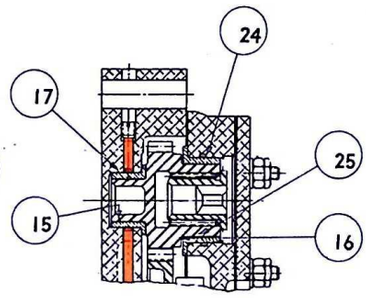
JANUARY 1945



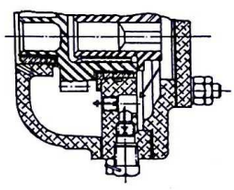
SECTION B - B



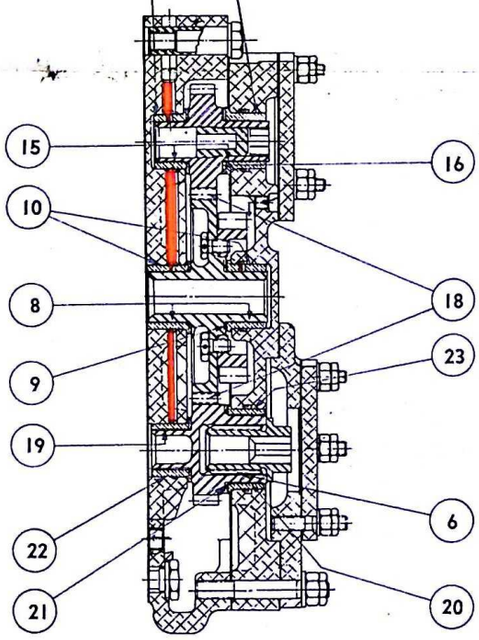
SECTION THRU UPPER VACUUM PUMP DRIVE COUPLING HAVING INVOLUTE SPLINE (SPECIAL)



SECTION THRU UPPER VACUUM PUMP DRIVE COUPLING HAVING INVOLUTE SPLINE (STANDARD)



SECTION F-F



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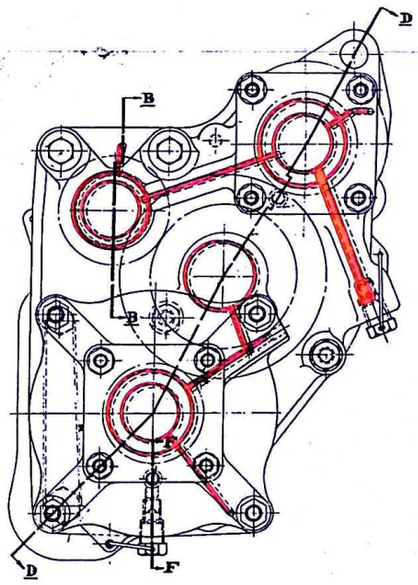


DUAL ACCESSORY DRIVE

NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. 30
PRESSURE SYSTEM SCAVENGE SYSTEM

WRIGHT AERONAUTICAL CORPORATION
A DIVISION OF CURTISS-WRIGHT CORPORATION
PATERSON, NEW JERSEY, U. S. A.

PART NO. 853569
(DRAWING NO. 410150)
NOT TO SCALE

WRIGHT CYCLONE ENGINES

SERIES 9HC

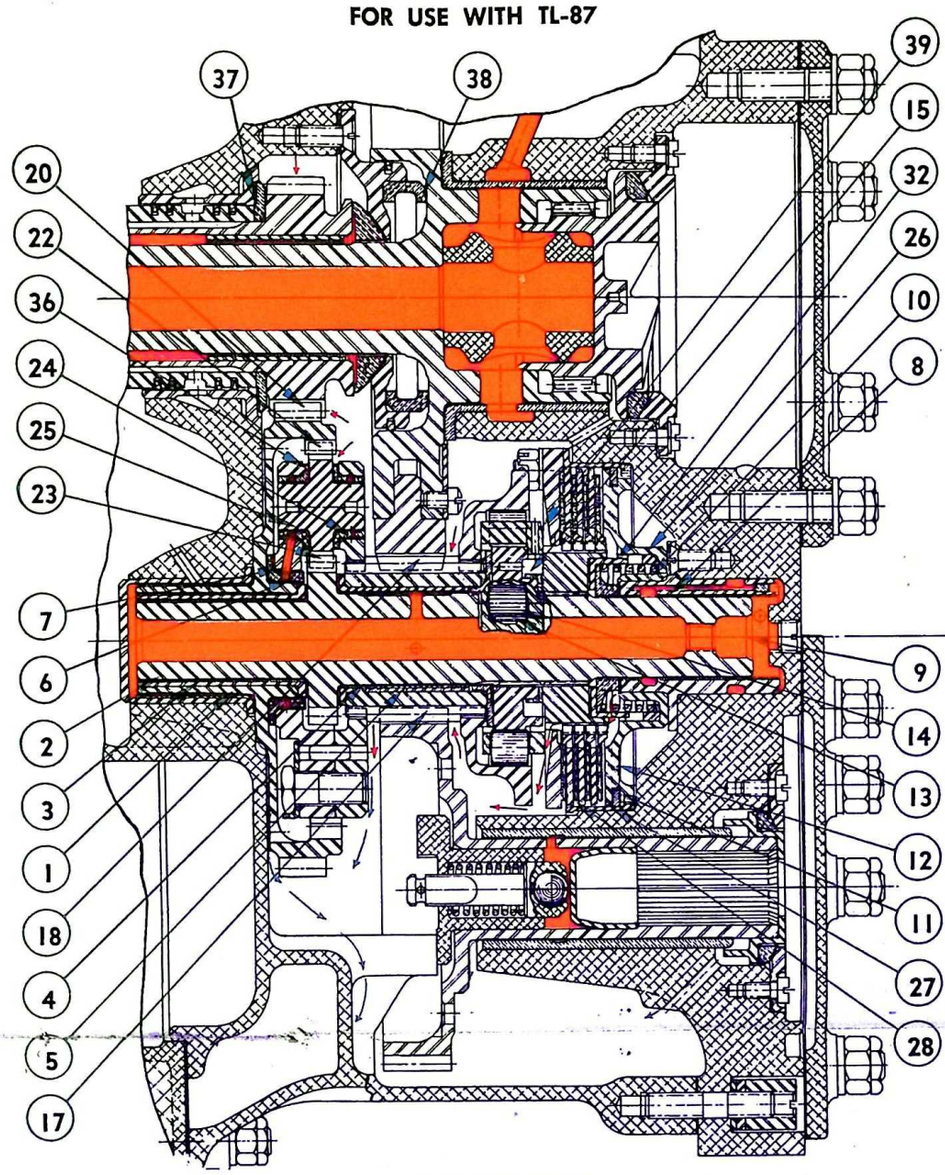
LIMITS AND LUBRICATION CHART

CHART NO. 30

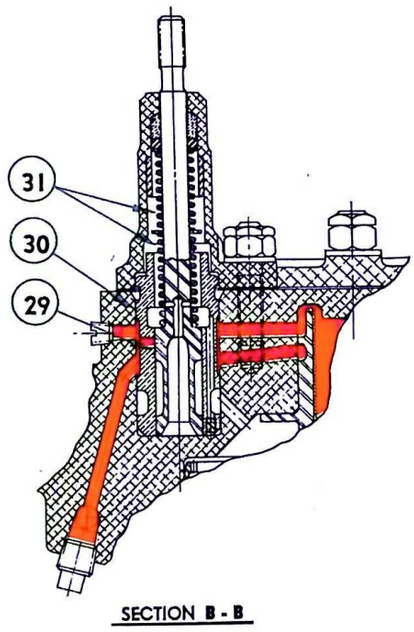
TWO-SPEED SUPERCHARGER (ROLLER CLUTCH TYPE)

FOR USE WITH TL-87

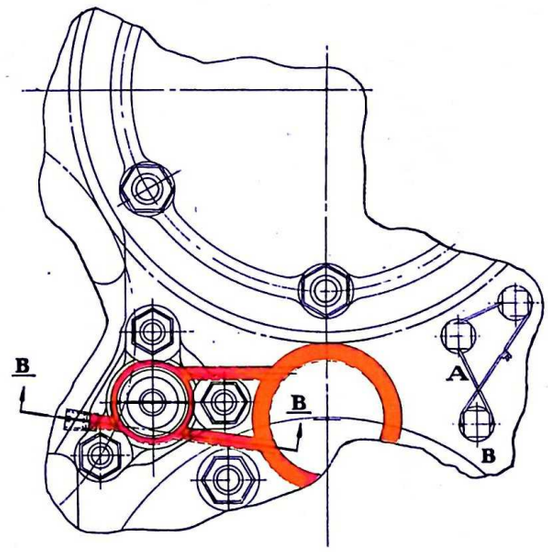
JANUARY 1945



7.134:1 & 10.04:1 RATIOS



SECTION B - B



VIEW SHOWING
SUPERCHARGER CLUTCH OIL CONTROL VALVE

NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. 87

PRESSURE SYSTEM SCAVENGE SYSTEM

WRIGHT AERONAUTICAL CORPORATION

A DIVISION OF CURTISS-WRIGHT CORPORATION

PATERSON, NEW JERSEY, U. S. A.

PART NO. 853573
(DRAWING NO. 416189)
NOT TO SCALE

WRIGHT CYCLONE ENGINES

SERIES 9HC

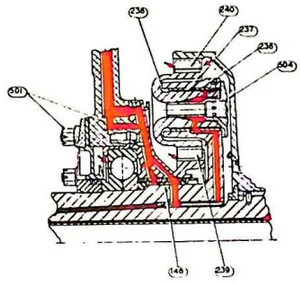
LIMITS AND LUBRICATION CHART

CHART NO. 31

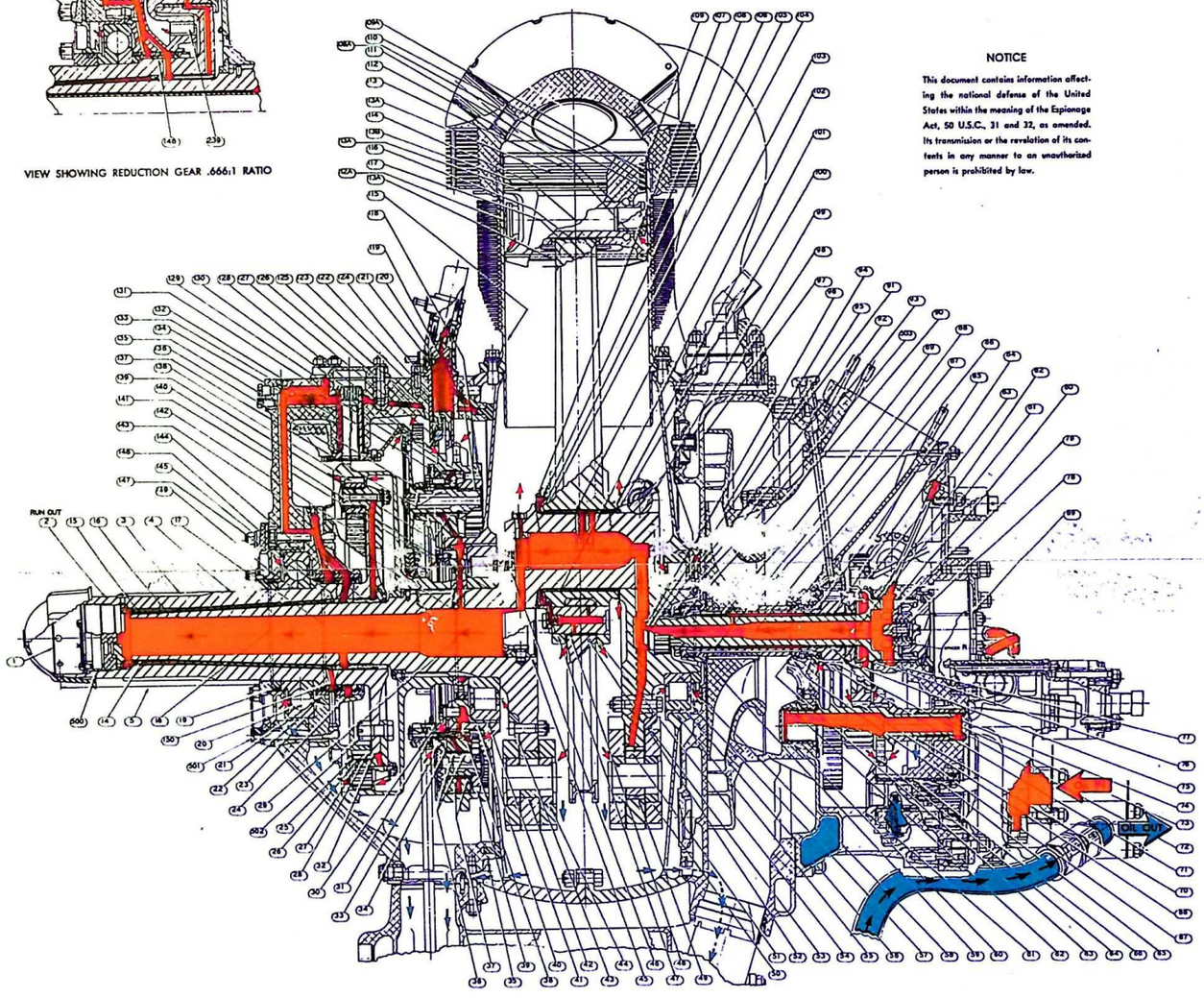
LONGITUDINAL SECTION

FOR USE WITH TL-101

JANUARY 1945



VIEW SHOWING REDUCTION GEAR .666:1 RATIO



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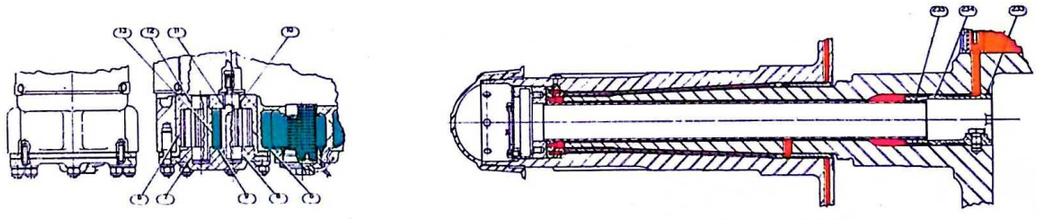
This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, 50 U.S.C., 31 and 32, as amended. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.



VIEW SHOWING ALTERNATE CRANKSHAFT WITH BREATHER TUBE

NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. 101

PRESSURE SYSTEM SCAVENGE SYSTEM

OPERATING OIL

WRIGHT AERONAUTICAL CORPORATION

A DIVISION OF CURTISS-WRIGHT CORPORATION

PATERSON, NEW JERSEY, U. S. A.

PART NO. 854533

(DRAWING NO. 418420)

NOT TO SCALE

WRIGHT CYCLONE ENGINES

SERIES 9HC

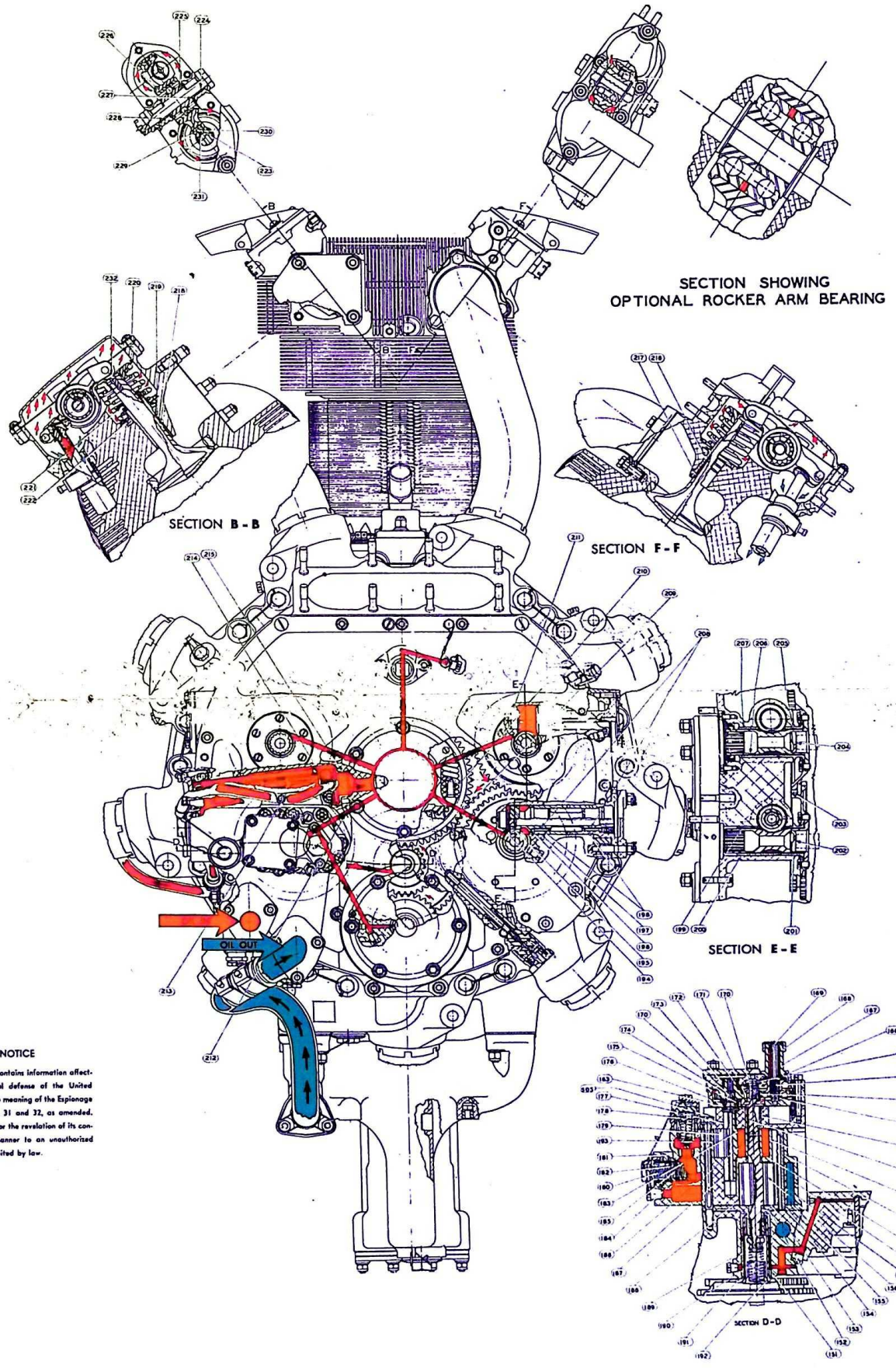
LIMITS AND LUBRICATION CHART

CHART NO. 32

ACCESSORY DRIVES SECTION

FOR USE WITH TL-101

JANUARY 1945



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NUMBERS REFER TO THE SERVICE CLEARANCES LISTED IN TABLE OF LIMITS NO. 101

PRESSURE SYSTEM SCAVENGE SYSTEM

WRIGHT AERONAUTICAL CORPORATION

A DIVISION OF CURTISS-WRIGHT CORPORATION

PATERSON, NEW JERSEY, U. S. A.

PART NO. 854534

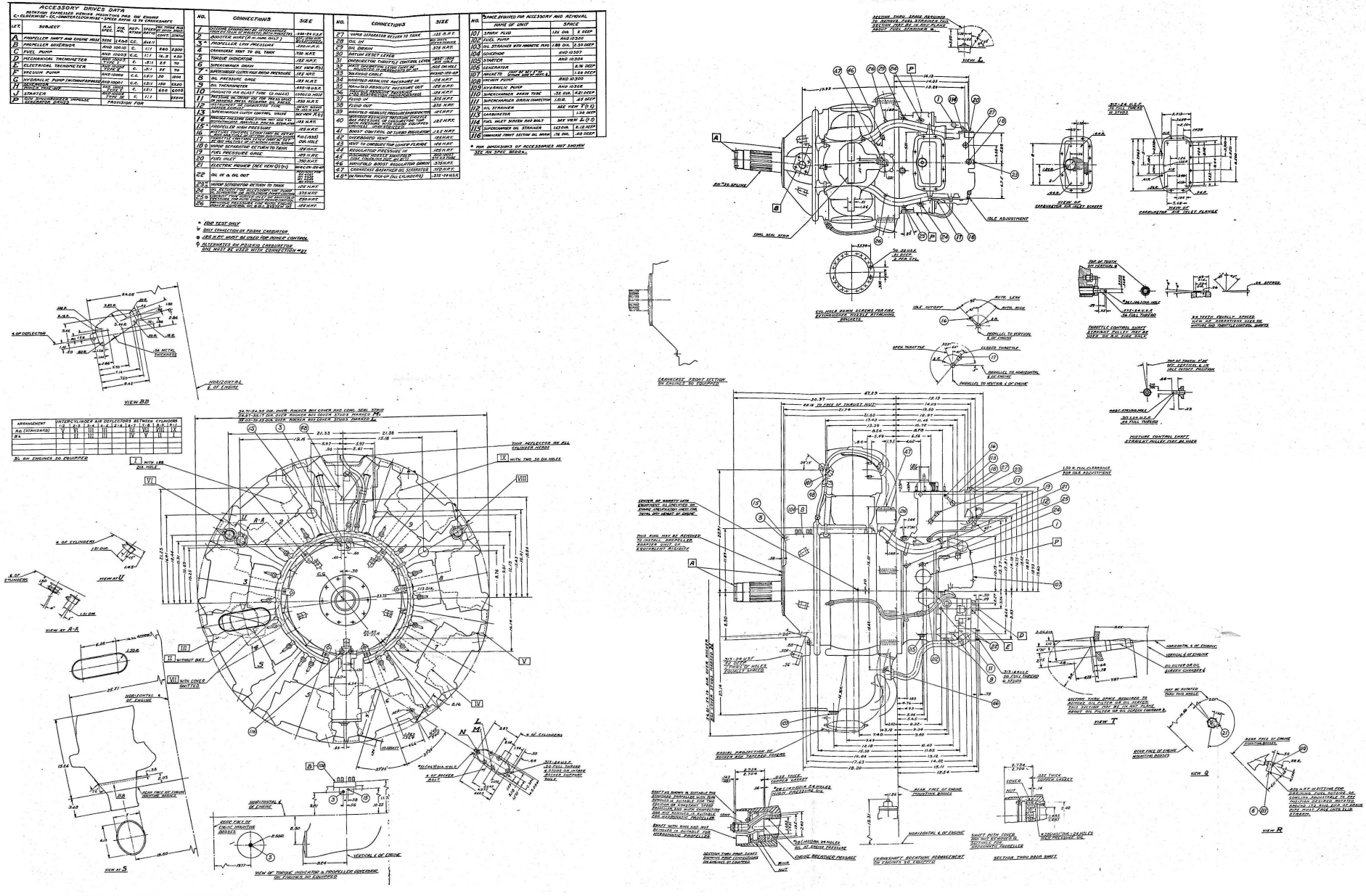
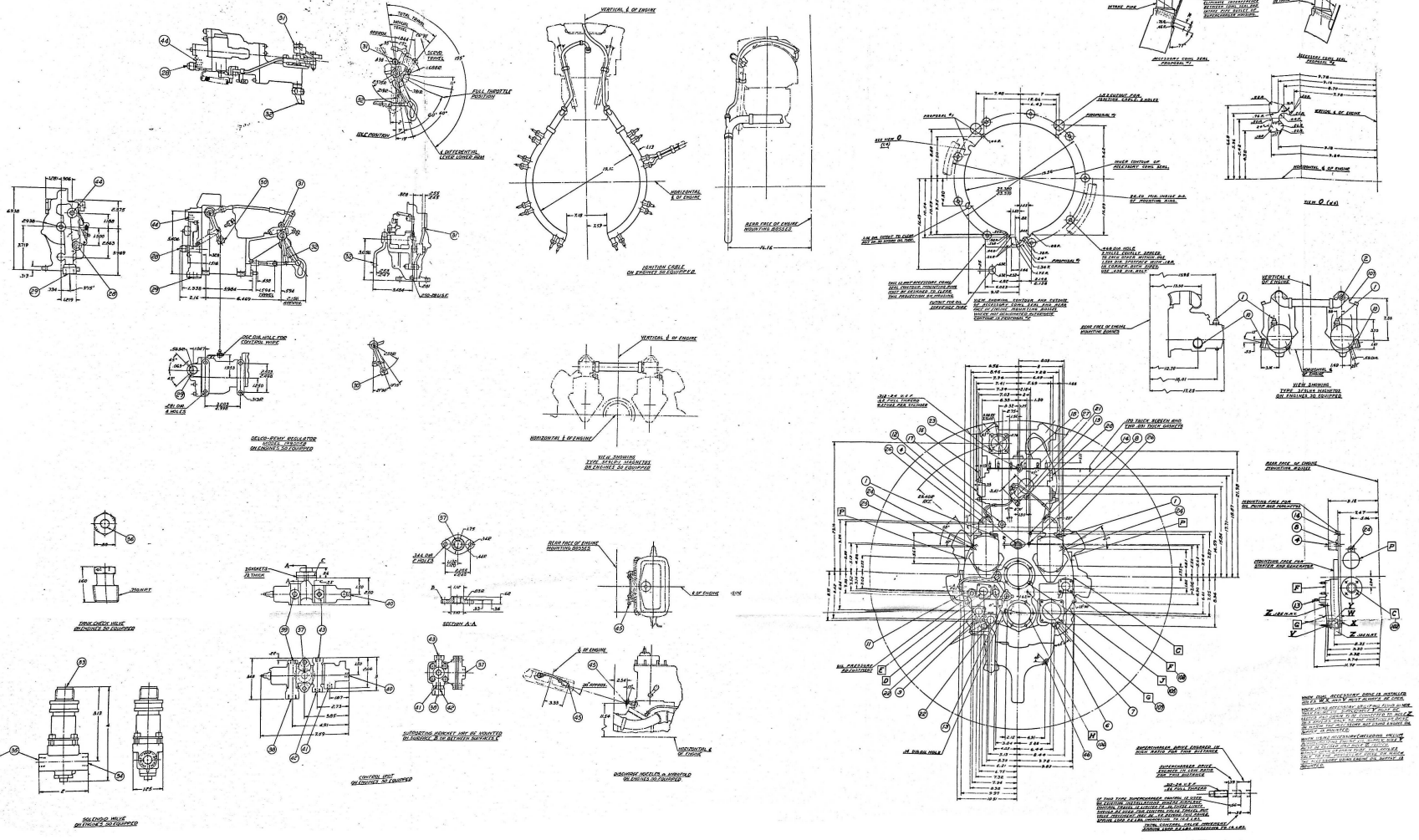
(DRAWING NO. 418420)

NOT TO SCALE

WRIGHT AIRCRAFT ENGINES
CYCLONE 9HC

Drawing No. 420565

SHEET 1 OF 2 SHEETS



WRIGHT AIRCRAFT ENGINES
CYCLONE 9HC
Drawing No. 420565
SHEET 2 OF 2 SHEETS